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Hope will launch the UAE to new heights in space exploration



Welcome

We've got plenty to keep you entertained this month - from exploding stars to the search

for white holes and the latest space news to our full guide to kick-start your summer of observing: there's something for everyone, whether you're an armchair or observational astronomer - or even a bit of both!

What's piqued our interest this time around though - and takes centre stage on our cover - is the existence of antigravity: rather than pulling everything that has mass down, this 'force' may actually throw everything upwards.

If you imagined it to be something from science fiction, you'd be right - it's featured in H. G. Wells' *The First Men in the Moon*, among other works - but the concept doesn't stop there. As you'll find this issue,

it could very much be a reality as physicists not only attempt to recreate it, but also search for it elsewhere in the universe. Could it really exist? You're about to find out!

This issue, 106, is of massive importance to me as it marks my 100th issue of working on the magazine - in that time our theories of space and time have altered, we've made some groundbreaking discoveries and space agencies have sent missions to other worlds beyond our own. It's been quite an exciting adventure!

Enjoy the issue, and don't forget to claim your free eBooks, which include *Book of the Moon*, *Book of Mars* as well as our guide, *Astronomy for Beginners*.


Gemma Lavender
Editor-in-Chief

Our contributors include...



Libby Plummer
Science & tech writer

Turn to page 32 for Libby's full scoop on how we'll be exploring the universe with the help of tech giants, including Microsoft, by using virtual reality.



Akhil Rao
Professor of economics

Akhil reveals the true damage of space debris as part of our question-and-answer session with the world's leading scientists.



Oliver Witasse
Planetary scientist

Oliver reveals the ESA's first mission to the Jupiter system as the space agency hopes to get up close to the gas giant's frozen and possibly life-bearing moons.



Nicky Jenner
Space science writer

Will we ever find white holes? We could be tantalisingly close according to Nicky's latest report on whether they could be added to the list of discoveries.

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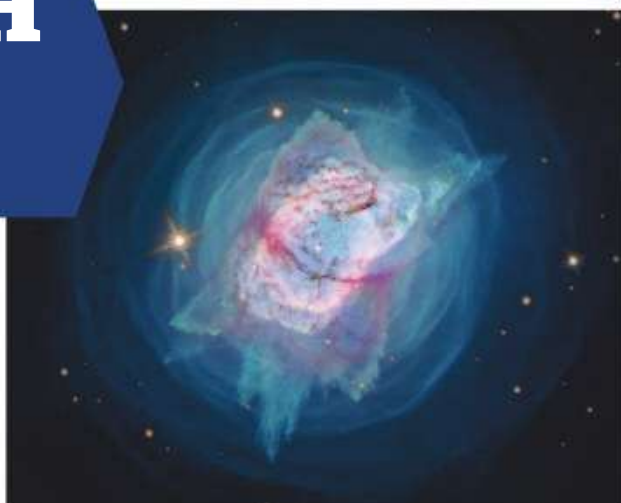
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YOUR FIRST CONTACT WITH THE UNIVERSE

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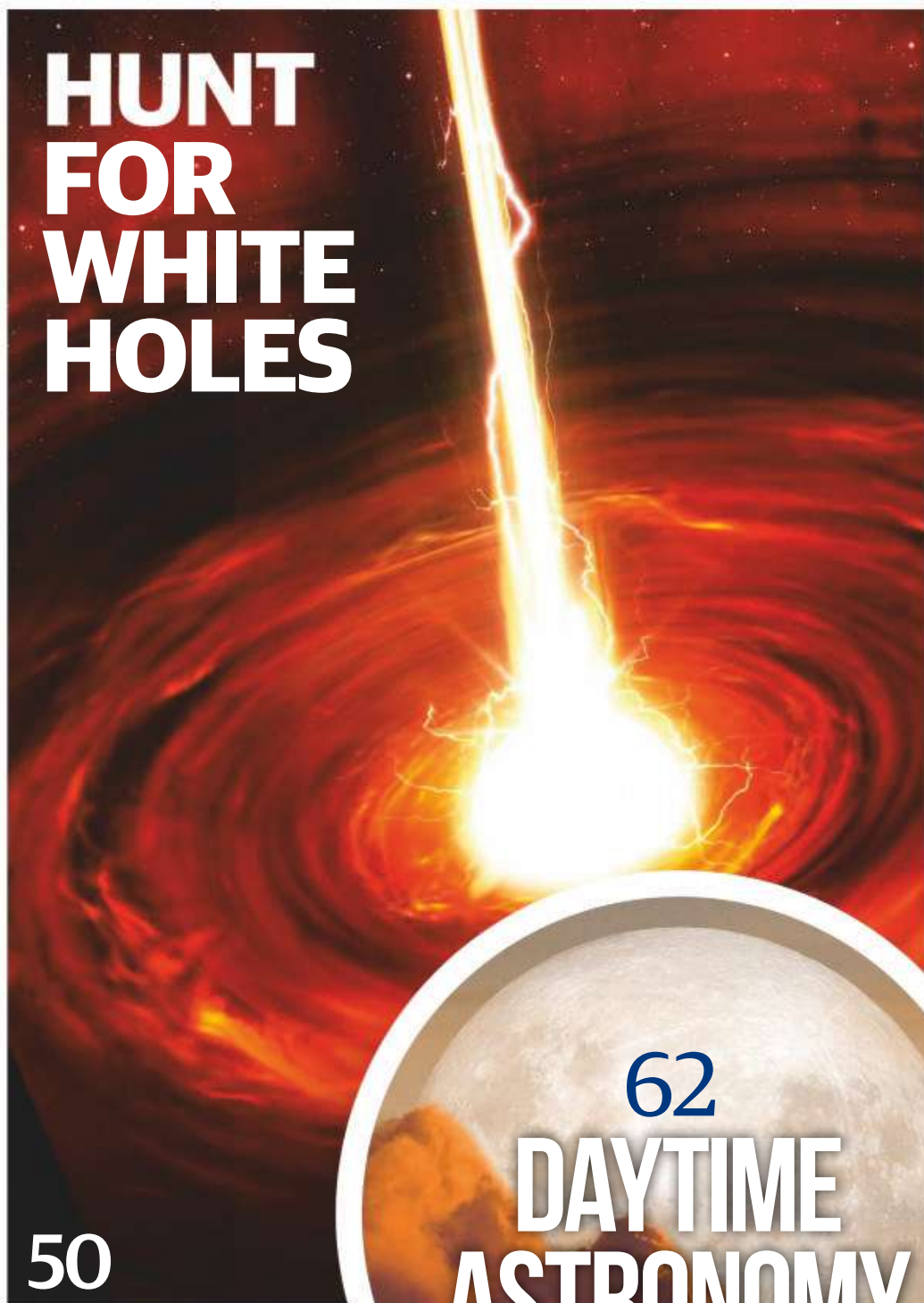


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A galaxy on a knife's edge

Another Hubble Space Telescope gem was captured recently when it photographed a galaxy called NGC 5907, also known as the Knife Edge Galaxy. This picture shows the structure – located roughly 500 million light years away – stretched across Hubble's keen field of view.

NGC 5907 is a spiral galaxy that clearly exhibits individual spiral arms, comprised of dust tracks that dampen the starlight to create black streaks. Because of NGC 5907's orientation in relation to Earth, Hubble is not able to get a bird's-eye view of the galaxy's core, but can still provide a unique look at the spiral arms from an alternative perspective.

© NASA/ESA & Hubble



The Butterfly Nebula's chaos

This image of NGC 6302 has been taken by Hubble in order to understand the outflow of gas and dust from the bipolar nebula's chaotic core. A distinct S-shape can be seen in the shot, coloured a reddish-orange hue. This outflow is comparable to a garden sprinkler, where instead of water, gas is thrown out in a way that creates the Butterfly's iconic shape. It's thought to be the same kind of rapid spinning that's taking place between two or more stars at the nebula's 'dying' centre.

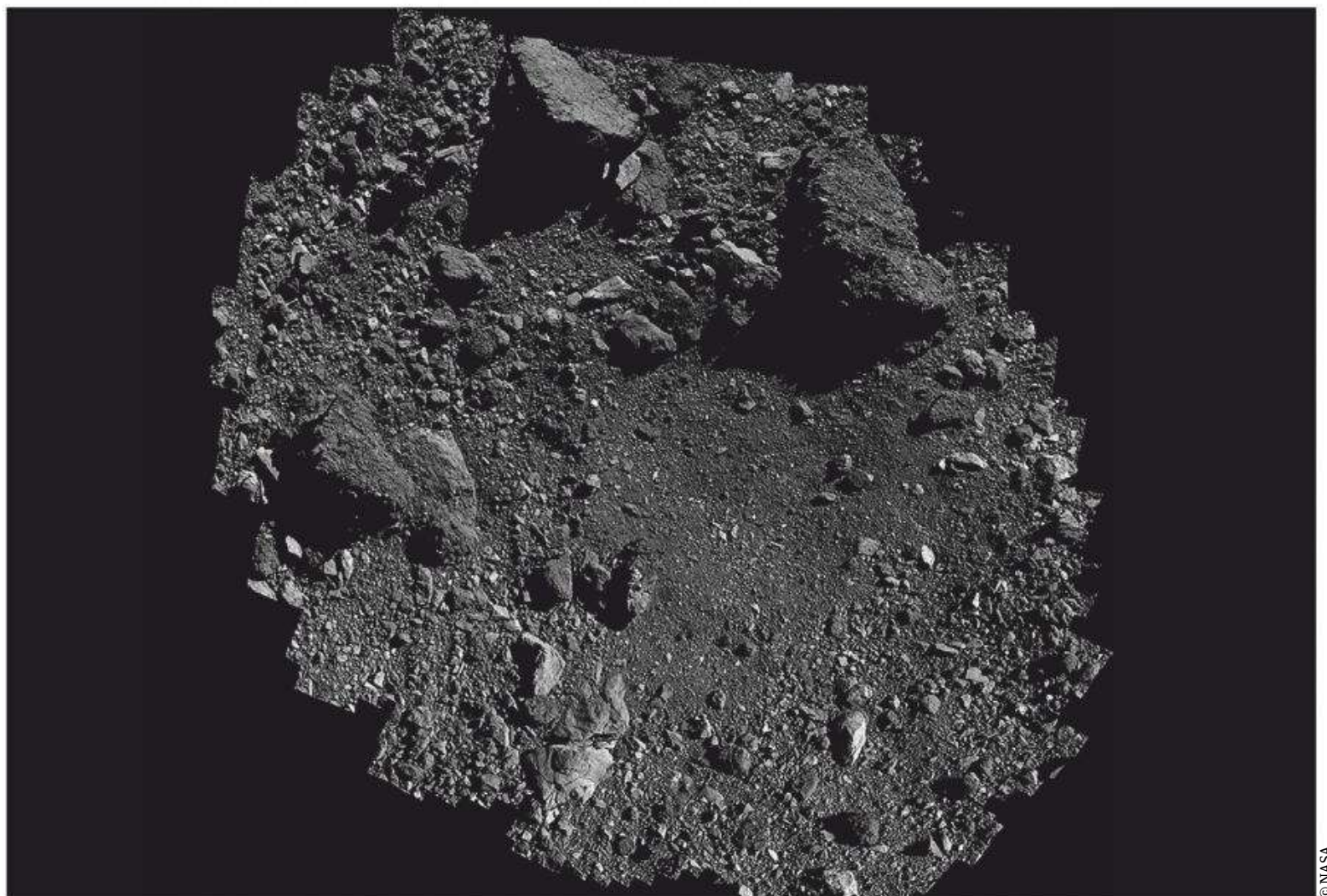
© NASA/ESA





Asteroid Bennu mosaic

NASA has a spacecraft in orbit around an asteroid that will eventually conduct a sample collection and return. OSIRIS-REx has been orbiting the asteroid Bennu since December 2018, and has been mapping the surface of this ancient, rocky relic ever since. This picture is a mosaic made up of 345 images showing a site on Bennu called Nightingale, which will receive a visit from OSIRIS-REx when it conducts its historic regolith collection exercise on 20 October 2020.



© NASA

Hunting for exoplanets in Chile

Underneath the glimmering Milky Way is one of the European Southern Observatory's three 60-centimetre (24-inch) telescopes that contributes to the ExTrA - Exoplanets in Transits and their Atmospheres - project. This venture is dedicated to investigating Earth-sized exoplanets in our galaxy and their atmospheres, and there is no better place to do so than at La Silla Observatory in Chile.

La Silla is located in the Atacama Desert, and it flaunts arguably the most amazing and consistent conditions in the world for astronomical observations and astrophotography. This is because it remains - for the most part, at least - cloudless all year round and is miles away from any damming light pollution.



Falcon 9 rocket curve

On 13 June 2020 SpaceX launched more Starlink satellites to low-Earth orbit with the intention of providing global internet access. The launch provided this stunning time-lapse photograph, a common sight in SpaceX's gallery and one which shows the path of the rocket's trajectory.

The arc reveals different parts of a launch profile, spaced over a matter of minutes. First is the bright emission of the first-stage ignition. Next it decreases in brightness as the second, smaller stage takes over. After the satellites are placed into orbit, the blue streak shows the reusable rocket's path back to Earth.

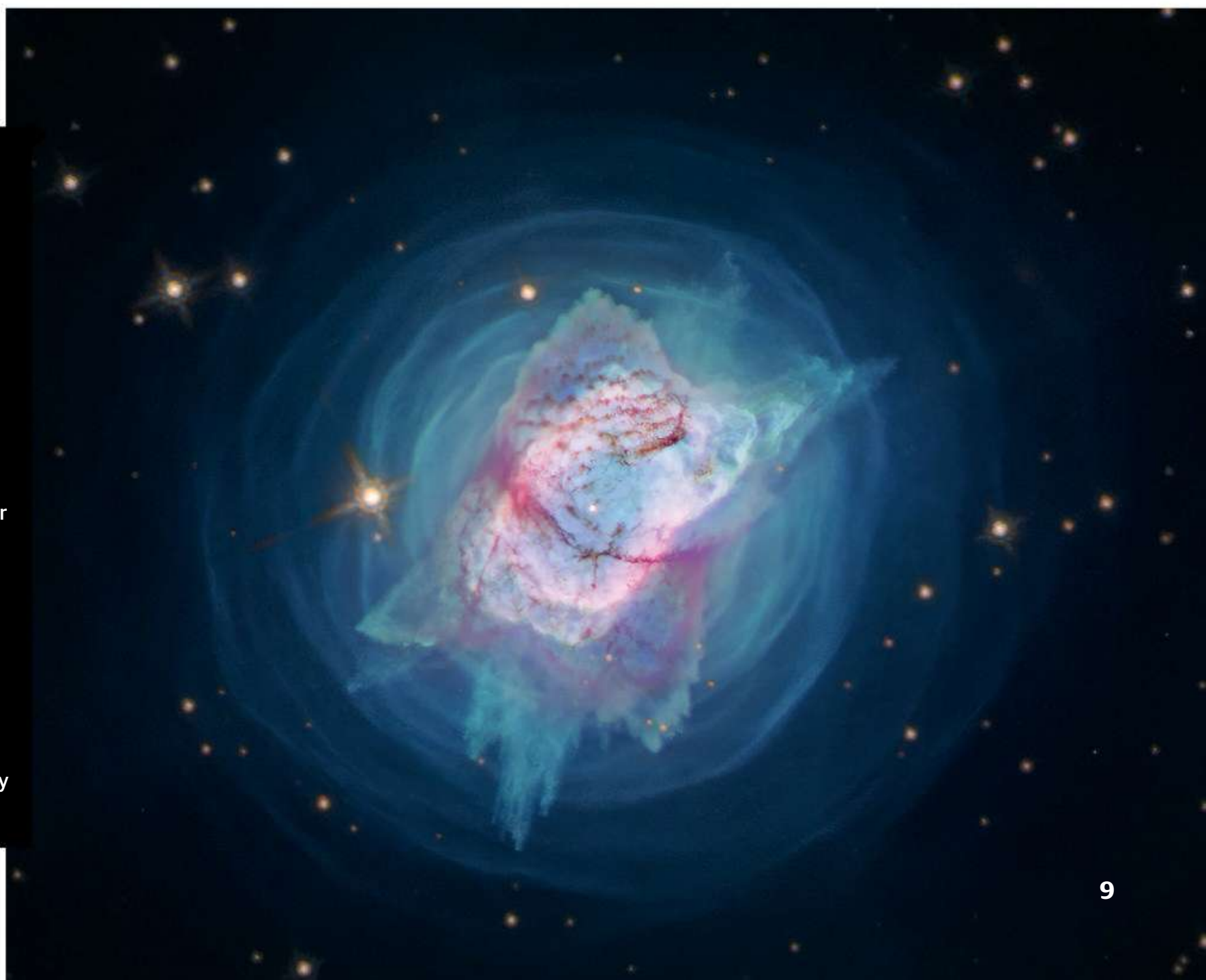
© SpaceX

The Jewel Bug Nebula

Hubble snapped this shot of NGC 7027, nicknamed the 'Jewel Bug Nebula', as part of the same study of the bipolar Butterfly Nebula on page 6. However, this stunning structure does not show the same intriguing S-shaped sprinkling of stellar material of NGC 6302.

Based on the patterns observed in this image, astronomers are able to speculate that the stellar core has spent centuries expelling its material slowly and quietly, which has culminated in this spherically symmetrical spectacle.

© NASA/ESA



The protostar
may provide
a snapshot
into our young
Solar System

Newborn star's X-rays shine light on Solar System's early days

Words by Chelsea Gohd

In a new study, astronomers report the first detection of X-rays from a Sun-like star in the earliest phase of its evolution. This discovery may help scientists explore the earliest days of our Solar System and rewrite cosmic history.

In 2017 the Chandra X-ray Observatory detected an X-ray flare coming from the very young star HOPS 383, which is the same type of star as our Sun. The star, known as a 'protostar' because it's in the earliest phase of star evolution, lies about 1,400 light years away from Earth and will grow to have about half the mass of our Sun.

In the new research, scientists studying the X-ray flare, which lasted for three hours and 20 minutes, gained insights that change our understanding of when stars like our Sun begin emitting high-energy radiation into space.

"We don't have a time machine that lets us directly observe our Sun as it was beginning its

life, but the next best thing is to look at analogues of it like HOPS 383," said Nicolas Grosso, of the Astrophysics Laboratory of Marseille at Aix-Marseille University in France. "From these we can reconstruct important parts of our own Solar System's past."

While scientists know that young stars more actively emit X-rays than older stars, it hasn't been clear exactly when stars begin emitting X-rays. According to Grosso and his team, the new finding "resets the timeline for when astronomers think Sun-like stars start blasting X-rays into space."

Originally, the researchers didn't observe X-rays coming from HOPS 383 outside of this flaring period, implying that outside of the flaring period the object was at least ten-times fainter than when the flare was at its maximum. They also found that the flare was 2,000-times more powerful than the brightest X-ray flare that has been observed from our Sun, a much older star.

Additionally, with stars this young there is often - as there is with HOPS 383 - a 'cocoon' of gas and dust that surrounds the star and falls inward towards a disc enveloping the central star. As the material falls inward, there is also an 'outflow' of material exiting the young system.

Grosso and his team observed so much outflow coming from HOPS 383 that he believes that the X-ray flare coming from this star could actually be powerful enough to strip electrons from atoms near the base of the outflow. It's thought that this process could be driving, or accelerating, the outflow via magnetic forces.

"If this connection between X-ray flares and outflows is correct, similar flares may have played an important role in forming our life-giving host star, the Sun," explained Kenji Hamaguchi of the Center for Research and Exploration in Space Science & Technology and NASA's Goddard Space Flight Center in Greenbelt, Maryland.

Teach the Curiosity rover how to drive on Mars

Words by Elizabeth Howell

A new online tool called AI4Mars, hosted on Zooniverse, allows anyone to label parts of the terrain in the landscape surrounding Curiosity, which has been roving on Mars since 2012. The tool is a form of 'machine learning' that allows rover planners assisting with Curiosity's movements to train the rover's intelligence for safe route planning.

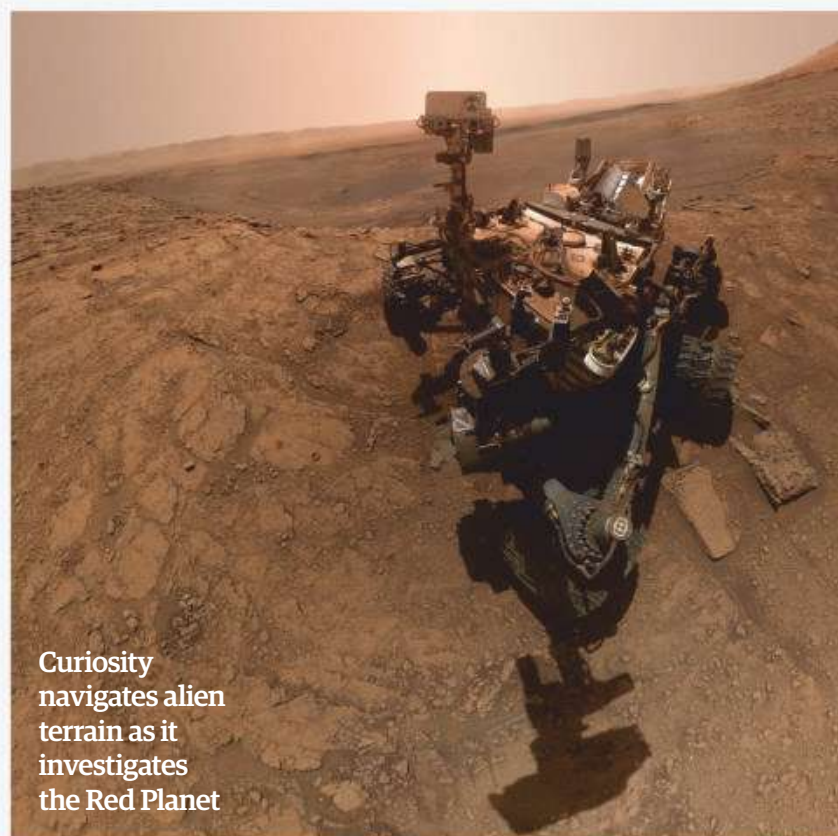
Picking an appropriate pathway is a pressing problem for Martian rovers. Curiosity's wheels wore down in the early years of its mission from driving over sharp rocks, while another Mars rover called Spirit got permanently stuck in a sand trap in 2010.

The first stage of training the algorithm, called SPOC - short for Soil Property and Object Classification - will allow it to distinguish between different types of terrain. SPOC is already used by Martian rover drivers, but bringing in the public will provide more training information at a faster pace.

The Curiosity rover's challenges are distinct from the self-driving car algorithms available, as the rover isn't working with roads, pedestrians or traffic signs. This means more help is needed to get the algorithm trained quickly.

"In the future we hope this algorithm can become accurate enough to do other useful tasks, like predicting how likely a rover's wheels are to slip on different surfaces," Masahiro Ono, an artificial intelligence researcher at NASA's Jet

Propulsion Laboratory (JPL) in Pasadena, California, said. Curiosity's training will also give a boost to NASA's new Perseverance rover, which is expected to launch no earlier than 20 July for a landing on Mars in 2021. More than 8,000 Curiosity images are available on the AI4Mars site already, allowing the public to start labelling images to help Curiosity, and eventually Perseverance.



Curiosity navigates alien terrain as it investigates the Red Planet

©NASA/JPL-Caltech

Neptune's weird moon Triton to get visit from NASA spacecraft

Words by Samantha Mathewson

A possible new mission called Trident aims to explore Neptune's strange moon Triton. As Neptune's largest moon, Triton boasts an uncommon icy mixture on its surface, as well as other unique characteristics that could help scientists learn more about how bodies in the Solar System evolved. Trident is one of four mission concepts competing in the current round of NASA's Discovery program, which develops relatively low-cost robotic-exploration efforts.

The proposed Trident mission - named for its three-pronged approach to solving Triton's mysteries and inspired by the three-pronged spear carried by the ancient Roman sea god Neptune - plans to visit Triton and study the moon's entire surface in greater detail.

"Triton has always been one of the most exciting and

intriguing bodies in the Solar System," explained Louise Prockter, director of the Lunar and Planetary Institute of the Universities Space Research Association in Houston who leads the Trident proposal team. "I've always loved the Voyager 2 images and their tantalising glimpses of this bizarre, crazy moon that no one understands."

The Trident mission's primary goal is to study Triton's strange icy plumes - a feature scientists believe is caused by water from the interior being forced through the moon's thick, icy crust - much like on Enceladus.

If Trident finds a subsurface ocean is the source of the plumes, the discovery would expand scientists' understanding of where water might be found beyond Earth. The mission will also map the moon's surface and study it in greater detail.



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The Milky Way could be harbouring many intelligent alien civilisations

Words by Chelsea Gohd

According to a new study, there could be more than 30 civilisations capable of long-distance communication here in the Milky Way. Led by researchers at the University of Nottingham, they assumed that intelligent life not only exists off-Earth, but develops on other planets similarly to how it does on Earth. To estimate the number of intelligent civilisations in our galaxy, the team took into account two major 'Astrobiological Copernican limits' – conditions that such an 'intelligent' civilisation would depend on.

For one of these limiting factors, the researchers used Earth, where life began approximately 4.54 billion years ago, as an example. They assume that intelligent life most likely forms in less than 5 billion years. The second limiting criterion focused on stars. They estimate that a planet with intelligent life would orbit a star like our Sun. This Sun-like star would have "a metal content equal to that of the Sun... the Sun is relatively speaking quite metal-rich," said Tom Westby, an assistant professor at the University of Nottingham.

In addition to these two Astrobiological Copernican limiting criteria, the scientists factored



Above: Could there be other life in the Milky Way?

in technological capability. The researchers figured that the number of 'intelligent' civilisations depends on technological prowess, specifically how long they have been sending out some sort of signal into space – anything from radio transmissions from orbiting satellites to television. Using our civilisation as an example for a potential extraterrestrial one, the researchers estimated that humans have been 'technologically advanced' for about 100 years.

"We calculate that there should be around 36 active civilisations in our galaxy," said Westby. However, the average distance to these alien worlds would be approximately 17,000 light years – much too far for us to contact with existing technology.

Titan's odd patches are dry lake beds

Words by Mike Wall

Strange bright patches observed in the southern tropical regions of Saturn moon Titan over a decade ago are likely the beds of dried-up hydrocarbon lakes and seas. The observations could shed light on Titan's climate history and inform the hunt for potentially habitable environments.

The patches were viewed as likely evidence of lakes or seas on Titan, which was widely expected to harbour such bodies, said Jason Hofgartner of NASA's Jet Propulsion Laboratory in Pasadena, California. That early expectation was borne out after NASA's Cassini spacecraft arrived in orbit around Saturn in 2004.

But the lakes spotted by Cassini sit primarily near Titan's poles, especially the moon's far-northern reaches. The probe didn't see bodies of liquid where bright patches detected by the Arecibo and Green Bank dishes lie, in the southern tropics.

The researchers tied the reflective patches identified by the radio telescopes to a single 'terrain unit', which has smoother surfaces and a different composition than the surrounding landscape. Such features are characteristic of dry lake or sea beds, said Hofgartner.

© NASA/JPL-Caltech

Mysterious 'fast radio bursts' found firing rhythmically through cosmos

Words by Charles Q. Choi

Mysterious pulses of radio waves from deep space can fire in regular patterns, a discovery that might help shed light on the cause of these puzzling outbursts, a new research finds. Fast radio bursts, or FRBs, are intense pulses of radio waves that can emit more energy in a few thousandths of a second than the Sun does in nearly a century.

The mystery of FRBs increased when scientists discovered the first repeating FRB in 2016. When astronomers see repeating patterns in celestial events, they often think rotation might play a role – for instance, a fast-spinning neutron star known as a pulsar, which blasts radio waves from its magnetic poles, flashing like a lighthouse from the perspective of Earth. However, radio bursts detected in previous events appeared sporadically, with random timing. Now, for the first time, a fast radio burst that generates a regular pattern of bursts has been discovered.

Scientists analysed the repeating FRB 180916.J0158+65 using the Canadian Hydrogen Intensity Mapping Experiment (CHIME) radio telescope in Okanagan Falls, Canada. FRB 180916.J0158+65 would fire off bursts for about five days, with most bursts concentrated in a stretch about 14 hours long, then go dormant for about 11 days before starting the cycle all over again.

Left: The new FRB follows a repetitive pattern

Right: Titan is a prime candidate in the search for life



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In search of antigravity

WHEN SPACE IS THE ANTIGRAVITY

THROWN UPWARDS GRAVITY

It's the force that throws objects up, and if found it could be the holy grail for space travel among the stars

Straddling the Franco-Swiss border near Geneva lies the European Organization for Nuclear Research, more popularly known as CERN.

This laboratory houses the accelerators, detectors and equipment comprising a number of different particle physics experiments, including the famed Large Hadron Collider (LHC) responsible for discovering a particle suspected to be the Higgs boson, the so-called 'God particle', in 2012.

CERN's particle accelerators are designed to study the tiniest constituents of matter: the fundamental particles that form everything from stars and planets to your afternoon cup of tea.

This type of matter is known to scientists as 'baryonic matter'. The vast majority of what we see throughout the visible cosmos is formed of baryonic matter, comprising particles including protons, neutrons and electrons - the latter are not technically baryons, but are usually considered baryonic matter by most astronomers.

However, this is not the only particle world to exist. Every 'ordinary' particle we know of is accompanied by an antiparticle - a mirror image that has the same mass as its ordinary counterpart but opposing properties - charge, spin, quantum numbers, magnetic moment. The electron, for

example, has a charge of -1, and is partnered by the positron, which has a charge of +1. The proton partners the negatively charged antiproton, the neutron the antineutron and so on.

This exotic type of matter, known as antimatter, was first predicted to exist in the 1920s by British physicist Paul Dirac, and was discovered experimentally shortly after. Matter and antimatter particles are always produced in pairs, albeit spectacularly unfriendly ones. If the two meet and collide they destroy one another in a process known as annihilation, producing a burst of energy as both are wiped from existence.

Matter and antimatter should therefore be created in equal measure, and we would expect the Big Bang to have filled the universe with the same amount of each. These particles should have found their way to an opposing particle and annihilated over time, leaving an empty universe behind.

Controversially, we instead see a matter-filled universe and catch glimpses of antimatter only fleetingly during thunderstorms, natural radioactive decay and within phenomena such as cosmic rays. This implies that there may not be perfect symmetry between the processes at work within the matter and antimatter worlds, and that the laws of nature may not be mirrored between the two equal, yet opposing forces.

"Differences between the behaviour of matter and antimatter are embedded in our conventional theory, which is known as the Standard Model," says Professor Chris Parkes of the University of Manchester in the UK and leader of the university's involvement in the LHCb experiment at CERN's LHC. In fact, "the Nobel Prize was awarded in 2008 to the theoretical work that embedded this matter-antimatter asymmetry into the foundations of the Standard Model."

"DIFFERENCES BETWEEN THE BEHAVIOUR OF
MATTER AND ANTIMATTER ARE EMBEDDED IN OUR
CONVENTIONAL THEORY" CHRIS PARKES



Could
antigravity be
hiding away
in another
universe?

Gravity vs antigravity

If it exists, how does the supposed counterpart to space's familiar force behave?

Gravity

Gravity is the universe's weakest known force

Compared to the other three fundamental forces of nature – strong, electromagnetic and weak – gravity is known as the weakest, and as a consequence has a negligible influence on the behaviour of subatomic particles.

Matter



It's responsible for planets, stars and galaxies

Everything you can see in the universe is held together by gravity. It causes planetary motion around stars and is responsible for the evolution and appearance of the planets, stars and galaxies.



It gives weight on Earth

On our third rock from the Sun, gravity appears to act downwards and gives everyday objects their weight. It also causes the ocean tides with help from the orbital behaviour of the Sun and Moon.

It causes objects to gravitate towards each other

Gravity operates on all objects with mass, causing them to fall in towards each other. Since energy is similar to mass, it can also influence phenomena such as light.

Antigravity

Antigravity is the 'loss' of mass

The best way to describe antigravity is that it opposes gravity, creating an environment where objects don't seem to have any mass. These objects then tend to 'levitate' or fall upwards rather than downwards.

Anti matter



The Large Hadron Collider is hunting for it

Using the Antihydrogen Laser Physics Apparatus, also known as ALPHA, physicists mastered the tricky task of keeping antimatter around for long enough to look into how it behaves, providing a look into the possibility of antigravity.



It pushes space-time apart

Similar to dark energy, antigravity will push the fabric of space-time apart. If it exists then it would prove useful for keeping hypothetical constructs such as wormholes open for spacecraft to travel through them.

It could comprise of antigravitons

If we can prove that gravity is made up of gravitons then we may be able to assume that antigravity is comprised of its counterpart, the 'equal-but-opposite' antigraviton.

To explore this asymmetry, scientists turned to the fundamental forces of nature. There are four such forces: strong, weak, gravitational and electromagnetic. The strong force holds nuclei together, gravity is an attractive force between masses, electromagnetism governs charge and magnetism and the weak force facilitates decay.

This final force, the weak force, may play a part in some of the known asymmetries of matter and antimatter. Interactions between particles and the weak force appear to occasionally violate something known as 'CP-symmetry', in which particles with differing charges and parities are not affected equally – 'handedness' is a good analogy, with some particles being 'right-handed' and others 'left-handed'. As matter and antimatter particles have largely opposite properties by definition, they thus behave differently in the weak force domain on rare occasion, resulting in a different number of

interactions occurring for matter than antimatter over time.

This may have something to do with the surplus of matter we observe in the universe, but as with all open scientific questions, we are unsure of the full picture. Cosmologists suggest the Big Bang may simply have created more matter than antimatter for some reason, and it remains possible that while we see matter, all the antimatter is simply hiding elsewhere in the universe – or multiverse.

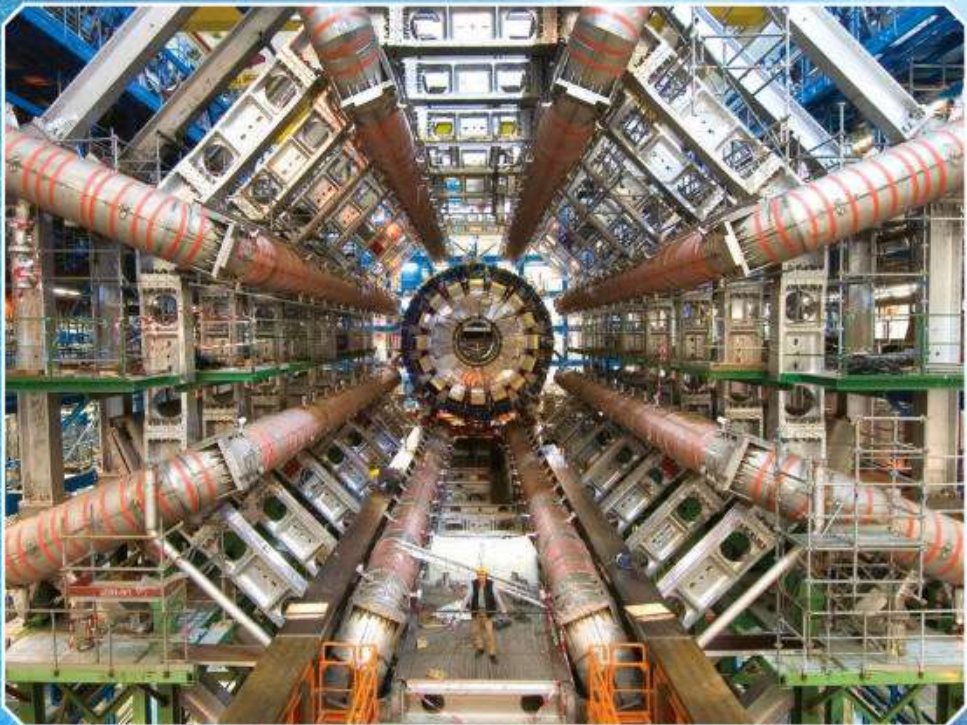
Antimatter-matter unbalance aside, we have a lot to learn about the exotic world of antimatter, and scientists are now exploring how another fundamental force interacts with antimatter: gravity.

"The gravitational force on antimatter has never been directly measured," says Daniel Kaplan of the Illinois Institute of Technology (IIT). "For all we know, antimatter might even fall up. This possibility is known as 'antigravity': gravitational

Left: Antigravity could help propel us to destinations beyond the confines of the Solar System



© Adrian Chesterman



The ATLAS experiment, which stands for A Toroidal LHC ApparatuS, has contributed in the search for antigravity, although to date results are inconclusive.

ATLAS

Focusing on the slight differences between matter and antimatter by studying 'beauty quarks', this experiment is incredibly useful in the hunt for antigravity.

LHCb

The Compact Muon Solenoid detector is designed to detect particles produced during the high-energy collisions carried out at CERN.

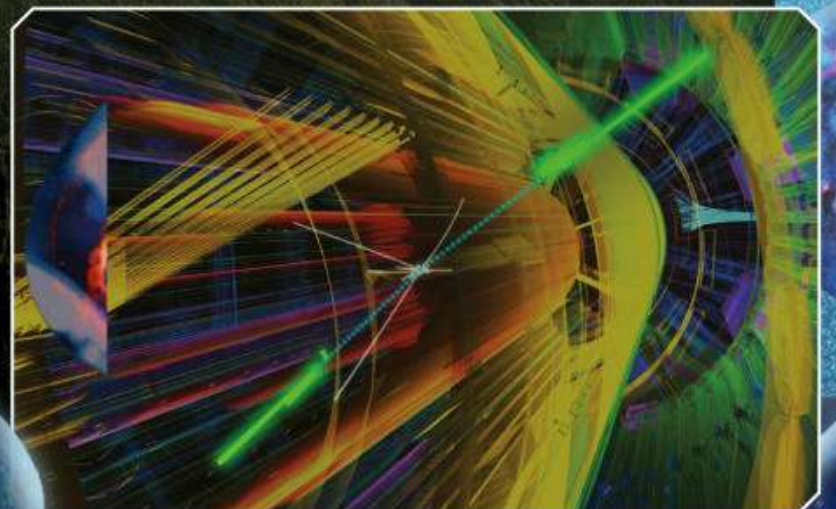
CMS

ALICE

A heavy-ion detector forming part of the LHC's ring, the A Large Ion Collider Experiment (ALICE) studies strongly interacting matter at extreme energy densities.

First started up in September 2008, the LHC is a 27-kilometre (16.7-mile) ring of superconducting magnets which smashes particles together at great speeds to investigate the quantum universe.

LHC



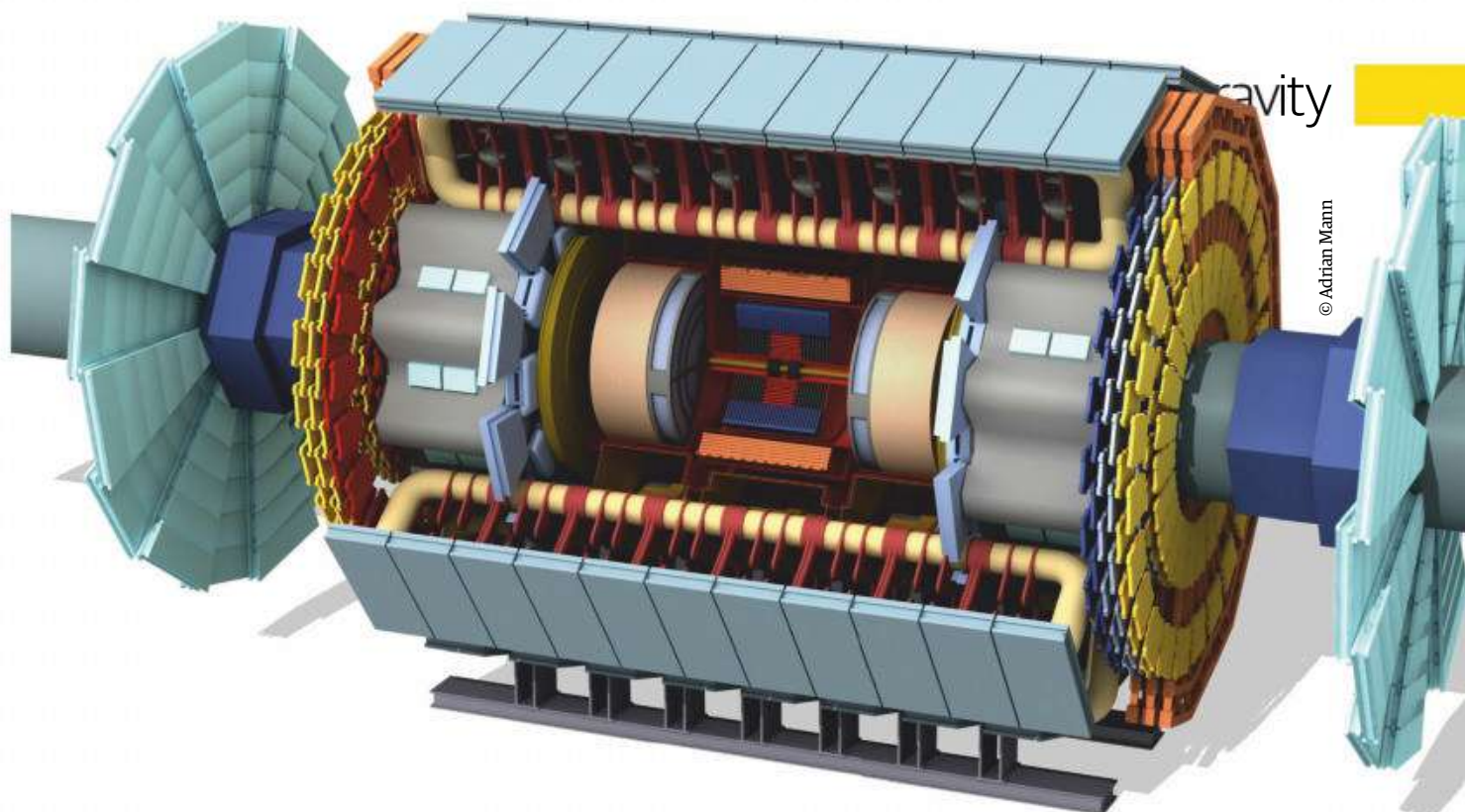
repulsion between matter and antimatter.” Gravity is an attractive force exerted by objects with mass. It causes massive bodies throughout the cosmos to draw in material from their surroundings and clump together, gives all objects on Earth an associated weight and keeps our feet firmly anchored to the ground.

“The established theory of gravity is Einstein’s theory of general relativity,” explains Kaplan. “This theory is in excellent agreement with all available evidence. However, there are reasons to believe it is wrong. For example, it is a ‘classical’ theory based on the assumptions that space and time are continuous, and that velocity, force and energy can have any value. Physicists believe these assumptions are incorrect, and that quantum theories represent the true nature of reality.”

While general relativity is well accepted and has been studied in depth for many years, aligning the theory with quantum mechanics, something that is at the forefront of current research, has proved difficult. Reconciling the two may be aided by matter-antimatter measurements to complement the largely matter-matter measurements that physicists are currently working with.

Some scientists propose that gravity may affect matter and antimatter differently, given the particles’ mirrored properties. Perhaps if you created a positron and set it free it would float rather than sink, feeling gravity as a repulsive force. However, this is an extremely controversial idea.

“There is no reason to assume that antimatter would fall upwards,” says Holger Müller of the



“THE GRAVITATIONAL FORCE ON ANTIMATTER HAS NEVER BEEN MEASURED... FOR ALL WE KNOW, ANTIMATTER MIGHT EVEN FALL UP” **DANIEL KAPLAN**

University of California, Berkeley, and a member of CERN’s ALPHA collaboration. “Unlike electricity, gravity doesn’t have ‘charges’ that could be positive or negative. There is not a shred of evidence for antigravity, and quite a lot of evidence against it.”

Svante Jonsell of Stockholm University, Sweden, agrees. “Almost no one would bet on antigravity, from either a theoretical or experimental standpoint,” he says. “If there was a difference [in the effect of gravity on matter and antimatter], that would really say that antimatter has some

as-yet-unknown property that’s different from matter, which would be a sensational discovery,” he continues. “But we know there are things about antimatter we don’t understand - most importantly why we don’t see as much antimatter as matter around us - so there are good reasons to probe its properties. And, of course, you cannot really know for sure until you have looked.”

However, it may not be a simple case of balloon and anvil - it may be one of anvil and an ever-so-slightly lighter anvil. “While it’s crazy to argue



Above: The LHC’s host of particle experiments are key in the search

Left: Physicists still can’t answer why matter is more abundant than baryonic matter throughout our universe



© Tobias Roetsch

Above: The Big Bang is thought to have filled the universe with matter and antimatter in equal measure, so why can't we find immediate evidence for antimatter?

"THERE IS NOT A SHRED OF EVIDENCE FOR ANTIGRAVITY, AND QUITE A LOT OF EVIDENCE AGAINST IT" HOLGER MÜLLER

that antimatter might 'fall up', you can make a serious case for looking for subtle changes in the acceleration of free fall," explains Müller. "Antimatter might fall down, but with a very slightly different acceleration compared to normal matter. Even this is hard to argue, but not crazy."

Even antigravity sceptics such as Müller admit that there is serious science to be done in this area, and several experiments are working to better understand gravity's relationship with antimatter. Many of CERN's collaborations and projects - a swarm of particle-physics acronyms including AEGIS, ATRAP, GBAR, BASE, ASACUSA and the aforementioned ALPHA - deal with antimatter and plan to precisely study its properties - and in some cases, free fall - in coming years. Several have already managed to create and trap antimatter. ALPHA has managed to create, trap and probe the gravitational acceleration of antihydrogen, and has plans to do so much more accurately.

"Measuring the acceleration of antimatter in the gravitational field of Earth is a crucial test of general relativity," explains Kaplan. "Only in recent years has it become feasible. ALPHA published the first limit in 2013, establishing that the gravitational acceleration of antihydrogen is no greater than 110 per cent, and no less than around 65 per cent that of matter. This clearly leaves the question of antigravity entirely open."

A problem with antimatter experiments is that the electromagnetic force overwhelms and distorts the effects of gravity for non-neutral particles.

Storing antiparticles, even neutral ones, is also incredibly difficult: the walls of any container or apparatus are necessarily formed of matter, which leads to quick annihilation. But there are glimmers of hope: CERN's Baryon Antibaryon Symmetry Experiment (BASE) has managed to somewhat circumvent this issue by using adequate magnets.

Accurately measuring antigravity, or any effect in that arena, requires far more precise measurements and advanced equipment. With this in mind, CERN is adding to its apparatus and will continue to further its antihydrogen research in coming years. Kaplan and IIT physicists are also developing the Muonium Antimatter Gravity Experiment (MAGE), which although still a work in progress would be capable of measuring minute differences in gravitational deflection on the order of mere picometres - 1 trillionth of a metre.

While most scientists believe that the difference between the gravitational acceleration of matter and antimatter is likely to be tiny, any difference at all would be hugely significant.

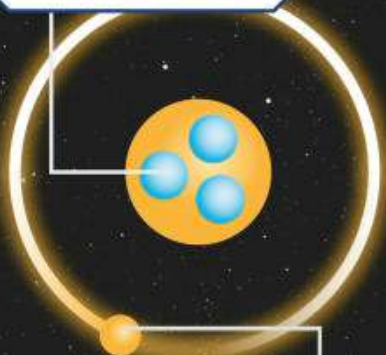
"Even a small discrepancy - for example, the gravitational acceleration of antimatter being larger or smaller than that of matter by as little as one part per million - would change our understanding of cosmology in important ways," says Kaplan. "Although most likely there would be no practical applications, antigravity would have enormous implications for the nature and evolution of the universe, possibly even eliminating the theoretical need for dark energy and dark matter."

Hydrogen

Proton

Mass: $1.67 \times 10^{-27} \text{kg}$

Charge: +1



Electron

Mass: $9.11 \times 10^{-31} \text{kg}$

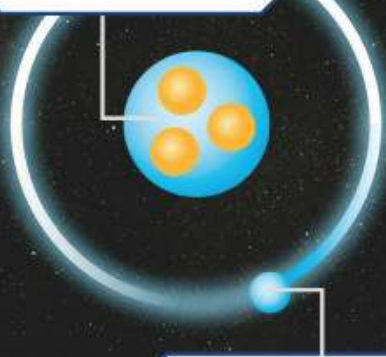
Charge: -1

Antihydrogen

Antiproton

Mass: $1.67 \times 10^{-27} \text{kg}$

Charge: -1



Positron

Mass: $9.11 \times 10^{-31} \text{kg}$

Charge: +1

What can antigravity be used for?

If proven to exist, this 'repulsive force' could assist in our quest to travel among the stars

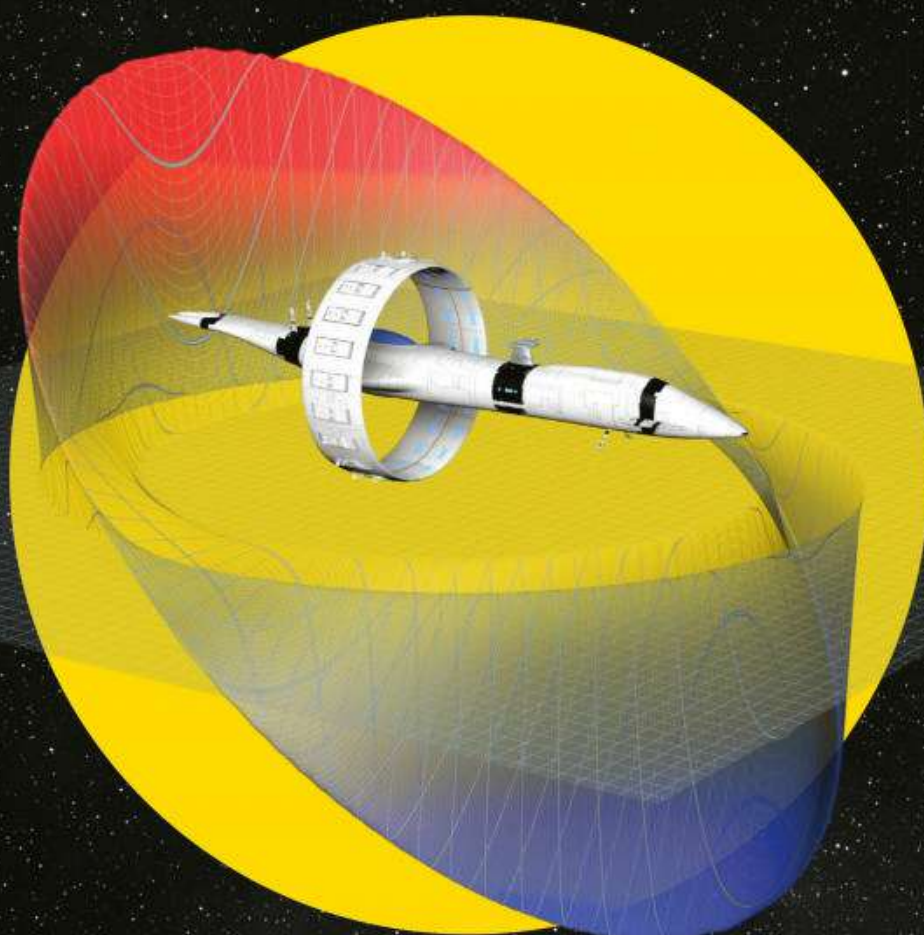
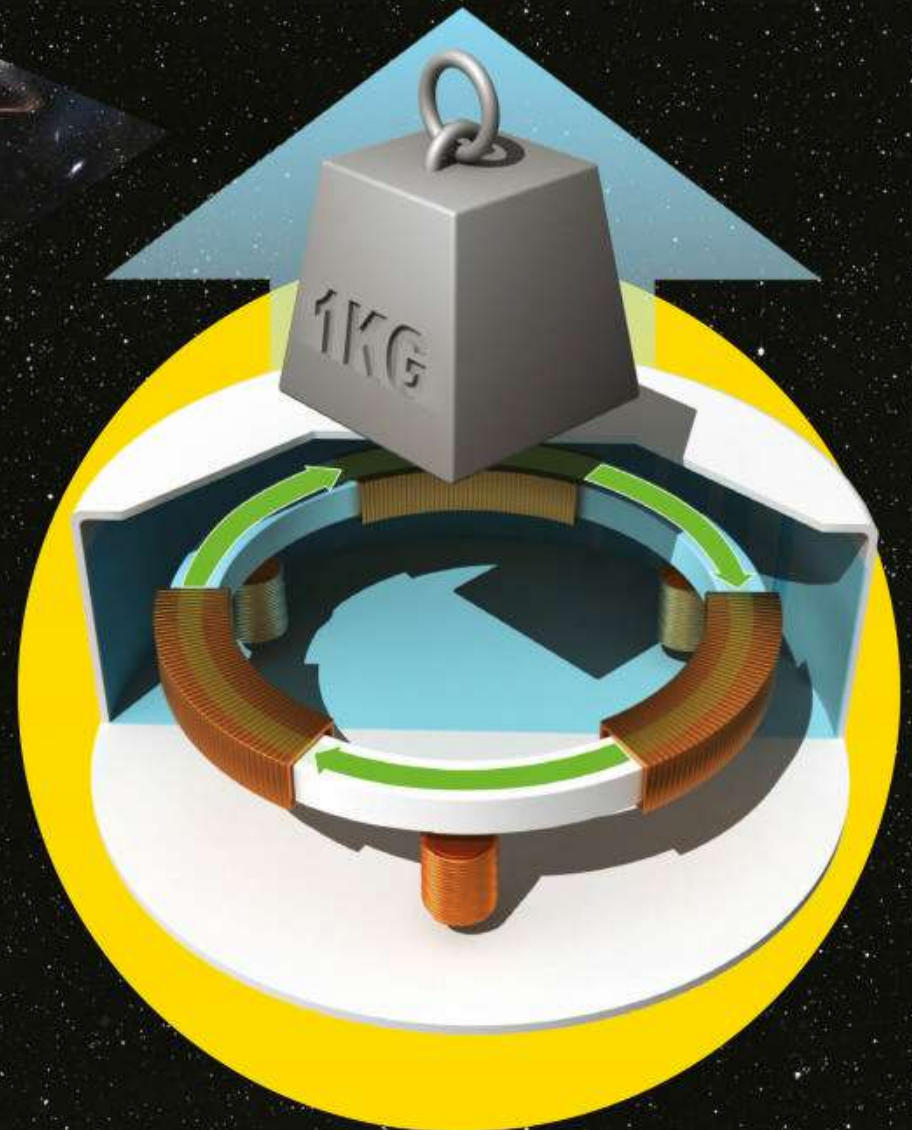


Opening up a wormhole

In theory antigravity could be used to open up a wormhole in order to allow spacecraft to dive straight in and travel straight through. By using a sufficient torrent of antigravity - which acts as negative energy - to force the throat of space-time apart, a path could be opened wide enough to enable an astronaut and their spacecraft to slip right through.

Gravity shields

Gravitational shielding involves shielding an object from the influence of a gravitational field. Currently bound to the pages of science fiction, gravity shields have the effect of reducing the weight of an object, assisting greatly with space travel.



Navigating space-time faster than light

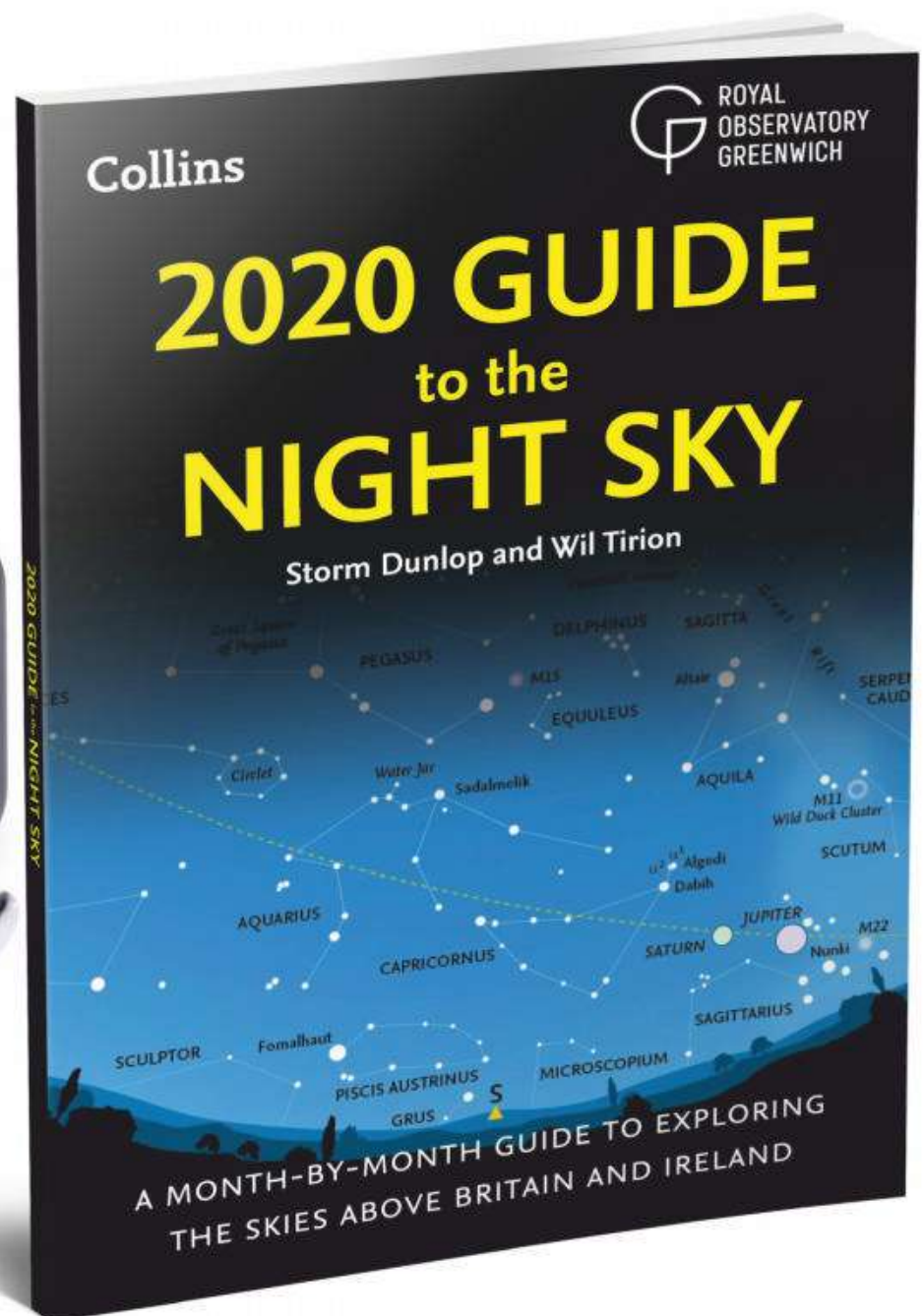
The Alcubierre warp drive, which is based on Einstein's field equations in general relativity, is a speculative idea by which a spacecraft could achieve apparent faster-than-light travel - that's if a configurable energy-density field lower than that of a vacuum is able to be created.

By creating antigravity, and a 'drainhole' to create the drive, the spacecraft would be shielded from external gravity and could even go below a black hole's horizon unscathed.

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WHAT ARE THE ODDS OF FINDING INTELLIGENT ALIEN LIFE?

Reported by Lee Cavendish

A NEW STUDY HAS PROVIDED SOME INTRIGUING ODDS ON THE EMERGENCE OF LIFE BASED ON EARTH'S OWN EVOLUTION

What is the likelihood that intelligent life could arise on another Earth-like planet under similar circumstances? This thought experiment offers the opportunity to imagine if the clock went back to zero on Earth - or an identical twin of our home planet - and deduce what the odds are that an intelligent species would evolve. This recent study was conducted by Dr David Kipping of Columbia University, New York, and it utilises a statistical tool known as Bayesian inference.

There have been many astronomers throughout time that have tried to find any indication of whether we are the only intelligent life to exist throughout the universe or whether there are other civilisations and species out there. Frank Drake's equation, devised in 1961, is one famous example of how astronomers have tried to calculate the number of possible intelligent extraterrestrial life forms mathematically, but it also demonstrates how many different parameters it depends on and how little is known about each parameter.

The statistical model used by Kipping allows some leeway for interpretation, but at the same time relies upon some very precise and key points. In a nutshell, Bayesian analysis combines prior beliefs and information to inform the probability of certain outcomes. However, an interesting aspect of this model is that it can change when new data becomes available. This is not an undisputed fact about life and intelligence coming into fruition elsewhere in the cosmos, but instead an important part of the conversation that will be updated and referred back to as time goes on.

Right: Astronomers are actively sending messages and trying to get a response. But is anyone even there?

"The technique is akin to betting odds," explains Kipping. "It encourages the repeated testing of new evidence against your position - in essence a positive feedback loop of refining your estimates of the likelihood of an event."

This thought experiment essentially repeats the Earth's evolution after the planet's formation, trying to figure out how likely it is for life and intelligence to arise again. For this to happen, Earth's history - as we currently understand it, at least - needs to be taken into account.

Earth has a defined habitable window that started approximately 4.2 billion years ago after a collision with a Mars-sized protoplanet called Theia, which formed our Moon. It took about 300 million years for Earth's oceans and atmosphere to return after the collision. Although it's impossible to look into the future, astronomers have calculated that in 900 million years, the Sun's luminosity will start to increase, ending Earth's habitability window and preventing the evolution of simple microbial life. In between these events, life began from chemical processes within inanimate organisms, known as abiogenesis, and intelligence slowly followed.

There has been much discussion about when life first began on Earth, and there are a few guesses. The strongest evidence, given by microfossils in the Earth's rock, show life was around 745 million years



Above: With more effort being made to discover new exoplanets, the number of known Earth-like planets could drastically increase

“THERE HAVE BEEN MANY ASTRONOMERS THAT HAVE TRIED TO FIND ANY INDICATION OF WHETHER WE ARE THE ONLY INTELLIGENT LIFE TO EXIST”



© Science Channel/Juaquin Cambron

Below: 300 million years after the Moon's creation, the habitability window opened



© Tobias Roetsch

after the planet became habitable, so 3.5 billion years ago.

The other, more disputed version of when abiogenesis arose on Earth is based on carbon-13-depleted zircon deposits found in Western Australia. This evidence says life was present just 300 million years after the planet first became habitable, so 3.9 billion years ago.

The next data point, when intelligent life arrived, is a bit more ambiguous. This is more of a prior assumption: one person may think that intelligence first reared its head when the first cities were built, while someone else could argue that it was when the first early hominids used fire. This parameter is a bit more subjective. Either way the difference in time is only a few hundred million years or so, and therefore it is relatively negligible when considering the timeframe of multiple billions of years. In the case of this study, signs of intelligent life arrived very recently, and very late on in the habitable window, approximately 4.1 billion years after the first signs of life.

At this point, Kipping narrows down the probabilities into four possible scenarios: life is common and so is intelligence, life is common

but intelligence is rare, life is rare but intelligence is common or the lonely universe scenario, which says life is rare and so is intelligence.

At this point it is best to think of the universe as a corner of a huge cosmic casino. There's a stellar game of blackjack going on in one corner and dark matter slots over in another. But in this game Kipping has been trying to figure out the odds of intelligent life emerging again on Earth-like planets using Bayesian statistical inference, which has interesting implications for long-sought-after alien life elsewhere in the universe.

From his complex calculations - based on an assumption that intelligence is rare and using the more disputed carbon-13-depleted zircon evidence - life is nine times more likely to arrive in a rapid

“THE SEARCH FOR INTELLIGENT LIFE IN WORLDS BEYOND EARTH SHOULD BE BY NO MEANS DISCOURAGED” DAVID KIPPING

fashion as opposed to being a rare and slow process. When Kipping applied the calculations to the microfossil evidence, the odds were still in favour of life being common, but by a factor of three. Either way it is clear that life is more likely to reemerge, given the chance, than to not.

Intelligence is a different question though. As previously mentioned, it seems as if the gap between life arriving and intelligence following suit is vast. There are many factors that can help or hinder it, and to take all of it into account is simply impossible. But with the same information and prior assumptions thrown into the Bayesian formula, Kipping has arrived at betting odds of 3:2 that intelligence is rare compared to it being common. This is not as favourable.

Based on this statistical model, Kipping recommends you put your chips on the scenario that abiogenesis is common and that its genesis can occur over a relatively short period of time - but intelligent life is not as lucky. However, Kipping does indicate that these are not overwhelming odds. In fact, it is remarkably close to being 50:50. This does not mean that half the amount of intelligent life would emerge, but if you had ten identical Earth-like planets, intelligent life would emerge on five of them.

Although this is an Earth-specific scenario, it does have implications about life arising on other planets. "The analysis can't provide certainties or guarantees, only statistical probabilities based on what happened here on Earth," Kipping says. "Yet encouragingly, the case for a universe teeming with life emerges as the favoured bet. The search for intelligent life in worlds beyond Earth should be by no means discouraged."

With astrobiology and exoplanet research gaining more momentum as technologies improve, space exploration missions become more ambitious and assumptions change, this model can be adjusted and the odds could improve. There is also more work to be done understanding technosignatures and the lifetime of civilisations in other planetary systems. Once again this points to the fact that more parameters must be scrutinised in order to hazard a clearer mathematical guess at alien intelligence being elsewhere in the universe.

Below: In 900 million years, microbial life will struggle to exist, thus ending Earth's habitable window

WHERE DO THE ODDS LIE?

If you had some money to bet on the existence of life and intelligence elsewhere, what would you bet on?



Earth's habitable window began 4.2 billion years ago after a young Earth collided with a Mars-sized body, dubbed Theia, 300 million years prior. Habitability only began when the oceans settled and the atmosphere returned to stability after the event.

The strongest evidence of ancient life, derived from microfossils, dates back to 3.5 billion years ago. The more disputed evidence, derived from carbon-13-depleted zircon sources, says life could have been around as early as 3.9 billion years ago.

It is hard to confine the inception of intelligent life and humanity's arrival. In the case of this study, Kipping states that the start of intelligence should date back to *Homo sapiens* emerging within the last half a million years, which is negligible when considering the grander timeframe.

We are currently living in the twilight years of Earth's habitable window, with less than a billion years left on the clock before the Sun heats up, starts pulling carbon dioxide out from rocks and making the air toxic and unbreathable.



INTERVIEW BIO

Dr Olivier Witasse

Witasse is a planetary scientist at the ESA who is based at the agency's European Space Research and Technology Centre (ESTEC) in Noordwijk, the Netherlands. He is also the project scientist for the ESA's upcoming JUpiter ICy moons Explorer (JUICE) spacecraft, due to launch in 2022 and arrive at Jupiter in 2029. Witasse has worked on a plethora of ESA-related space exploration missions including Mars Express, Venus Express, Cassini-Huygens, the ExoMars Trace Gas Orbiter and Chandrayaan-1.

EUROPE PLANS FOR AN ICY ENCOUNTER

The European Space Agency (ESA) is preparing for its first-ever mission to Jupiter's moons. **All About Space** speaks to the mission's project scientist, Olivier Witasse, to find out why the Galilean satellites are so appealing

Interviewed by Lee Cavendish

How have the moons that JUICE will be visiting - Ganymede, Callisto and Europa - sustained a subsurface ocean despite being so far away from the Sun? Why haven't they frozen over?

They are called 'icy moons' because they are made of frozen ice. But there is a mechanism inside the moons which generates heat, and then the ice can melt and become liquid. The question is, how is the heat generated inside?

Here we have two possible reasons. One answer is that because the moons are actually large, there are - like on Earth - some radioactive elements. Inside Earth, for example, there is heat generation coming from the interior from radioactive elements. But the other process, which is quite interesting, is that because the moons are relatively close to the very big planet Jupiter, and because of the characteristics of their orbits, there is a gravitational struggle. In fact, these moons don't have the shape of a normal ball - like a football - they are more like a rugby ball. They change shape because of the gravitational attraction between the moon and Jupiter. That makes the moon change shape and keeps the interior moving. That also generates some heat, and this heat allows the ice to melt and become liquid.

How were these subsurface oceans discovered?

The discovery of subsurface liquid water was one of the greatest discoveries in planetary science, which was made about 20 years ago by NASA's Galileo mission. The mission went around Jupiter, and the spacecraft needed a few flybys around the icy moons and Io. With its magnetometer it discovered that there is liquid water inside Europa, Ganymede and possibly Callisto.

That was a really great discovery because the measurements were not that obvious, because, you can imagine, we can't see it. It's inside the moon. It is done with the magnetic field. This liquid water is not pure water; it's salty water. It can change the magnetic field around the moon. And because the magnetic field around Jupiter is greater it changes the magnetic field a bit, and we could measure this change with the magnetometer.

The measurement indicated that there is liquid water inside Europa. There is liquid water inside Ganymede, the biggest moon of Jupiter. And for the last icy moon, which is Callisto, there was an indication that there was liquid water, but the measurement was not so easy to interpret.

Why was JUICE chosen as the first Large-class mission for the ESA's Cosmic Vision program?

The selection took place in 2012, and for any selection of missions, whether it's NASA or the ESA or any other space agency, it's always a very complex process. There is the call for ideas for missions. Then there are some studies. Then the ESA selects the mission based on some committees, which give a recommendation, and then they make some evaluations. All in all there are a lot of discussions that address all these questions, and at the end there is a committee in the ESA which decides what is best, given all these topics.

In 2012 there were three missions in competition. JUICE was one of them. The two others were a mission to study gravitational waves, which is now called LISA [Laser Interferometer Space Antenna], and the third mission was ATHENA [Advanced Telescope for High-ENERgy Astrophysics], which was an X-ray observatory.

Right: A scale model of JUICE's Radar for Icy Moons Exploration (RIME) antenna was recently tested at ESTEC





Left: A family portrait of Galilean moons.

From top to bottom: Io, Europa, Ganymede and Callisto

Below: The spacecraft's 10.5-metre (34-foot) magnetometer is just one of ten state-of-the-art instruments



These three missions were in competition, and after discussing the merits of each of them, JUICE appeared to be the best one. From what we see now, to me it looks like an obvious choice, because if you see the LISA mission on gravitational waves, it's very complex from the technology point of view. You need three spacecraft with which to do laser interferometry in space. It's very complicated. ATHENA poses a lot of challenges, and we see now that those missions are not ready to launch in 2022.

You've worked on many planetary science missions, such as the Cassini-Huygens mission, Venus Express, Mars Express and more. Based on your experience, how does the JUICE mission rank in terms of originality?

All missions are unique and interesting. Every mission is selected based on some science questions that are interesting at the time of their proposal and selection. All the previous missions on which I've worked are quite interesting, and they deliver a lot of amazing results. In the case of JUICE, what is very interesting is that for Europe, it's the first time we will go to Jupiter. It's a really challenging mission. We don't go to Jupiter all the time. This kind of mission is done every 30 years or so. That's why when we manage and develop such a mission we try to address all the possible science questions at Jupiter. In terms of science return, interdisciplinary science, it's really great because we address all kinds of questions. We're going to study the interior of the moons, their surfaces, their atmospheres, the link between the moons and Jupiter. We'll study Jupiter and the dust around Jupiter and the question of habitability.

The most interesting question that JUICE will address is the question of why we have this liquid water inside these moons of Jupiter. That's a question that we would like to understand better, because a very important objective of planetary science and astrobiology is to find possible places for life besides Earth. This is because we'd like to know if life can develop somewhere else besides Earth. That's the big question in science.

There are going to be ten scientific instruments on this spacecraft. Would you be able to single out two or three that you think will yield some exciting results?

As I said, we don't go to Jupiter every year, so once we reach such a mission we try to put the best instruments on the spacecraft. When the ten instruments were selected we tried to select the best possible payload for such an ambitious mission. In this case the payload was selected so that all the instruments could complement each other.

If you want me to select two or three, I would say the camera, JANUS, will be very interesting because it will deliver fantastic images not only of Jupiter, but of the surface of the moons at high resolution. It can image the surface better than ten metres (33

feet) per pixel, which means someone will really know what's going on on the surface, and it's always nice for the general public and the geologists and scientists in general.

Because we discussed the internal subsurface ocean, we have the magnetometer [J-MAG]. With the magnetometer we will detect the tiny variations of the magnetic field due to this ocean and we'll be able to - certainly in the case of Ganymede - know the depth of this ocean. We don't know if the ocean is ten kilometres [6.2 miles], 40 kilometres [24.8 miles] or even 50 kilometres [31 miles] deep, and we want to know the amount of liquid water. The magnetometer will give us this information, and information on the composition.

Another instrument which is also quite interesting is the laser altimeter, GALA. We will send lasers to the face of Ganymede and understand the little variations in altitude of the surface. This can help identify mountains or canyons or so on, but also it will see the variation of the change in the shape of the moon.

How much water is estimated to be in these icy moons compared to the amount on Earth?

What is amazing, surprising and fascinating is that we think there is more liquid water inside each moon than on Earth. We know the depth of our ocean, approximately ten kilometres [6.2 miles] maximum. But inside the icy moons the oceans are believed to be very big. They could be 50, 100 or even 200 kilometres [30, 60 or 125 miles] deep. That's much more than the little ten kilometres from the surface of Earth.

For example, at Europa it's possible there is twice the amount of liquid compared to Earth, and for Ganymede maybe five times.

What does this mission mean for our understanding of how the Solar System formed, and do you think this will completely change our definition of what a habitable world is?

First we are going to collect images and all the data in order to understand the system as it is now. Then, based on that, as a group of scientists we can do what we like to call the 'big picture'. We collect all the data and then extrapolate it through time, do some modelling, think about it and come up with some theories. Then we can get information on the origin of the moons.

It's very difficult to know what we can get out of the JUICE data, but I'm pretty sure that when we have the data from all the systems there will be an interesting outcome in terms of moon formation and origin.

As for the habitability, that will depend firstly on confirming that they have liquid water. Once we have confirmed that there is liquid water, then with the data set we are going to characterise these oceans. For example, how deep are the oceans?



Above: Cracks on the surface of Europa could be the result of Jupiter's gravity pulling it apart

Right: Future exploration of the moons could see an instrument drilling through the surface



“WHEN WE MANAGE AND DEVELOP SUCH A MISSION WE TRY TO ADDRESS ALL THE POSSIBLE SCIENCE QUESTIONS AT JUPITER”

What are the compositions? Where are they under the surface? Are they very close to the surface, or are they very deep inside the moons? All this information will be fed into the study of habitability, because the habitability of the ocean will depend on all these different factors.

The Cassini mission famously went through the water plumes found to be erupting from the surface of Saturn's moon Enceladus to study them. Is this something that you plan to do with the JUICE spacecraft?

Regarding water plumes in the Jupiter system, at the moment we have a hint that they possibly occur at Europa. It's not yet 100 per cent sure for a few reasons. The detection of those plumes is a bit complicated. Although in the case of Enceladus and the Cassini data, the plume is very clear. It was imaged. It was detected in all the data.

In the case of Europa, it is not yet clear. And for the other moons we have not detected anything. But with JUICE we are going to perform two close flybys at about 400 kilometres (250 feet) from the surface. Depending on the plume, we might go through the plume or not. But if JUICE does go through a plume, it's not a big problem because the plume is not something that can damage the spacecraft. I mean it will likely be a liquid vapour, so there will be no harm to the spacecraft. The problem would be that we'd need to adapt the trajectory to go through this plume, and that's a

bigger challenge. This is because the trajectory of JUICE is constrained by many, many topics. But if we can, we will do it.

This year marks the 410th anniversary of Galileo Galilei discovering the four 'Galilean moons' of Jupiter. In this time we've gone from seeing the moons through a telescope to actually planning a mission to go there. What do you think will be the future of the exploration of these moons?

You never know what the future will bring, but I think the next step after JUICE, depending on the results, of course, I think the next mission to Jupiter and to its moons will be a mission which lands on the surface of either Europa, Callisto or Ganymede. I think that could be the next step.

And if there is good information on the liquid water inside, what I would foresee is some element that would dive into the crust to reach the liquid water and explore it with a submarine, or something like that. I think that in the next 50 years we will see this kind of mission.

And then you've got technology advancing quite fast, so we are going to have to wait for ten more years to see the next human on another surface, which seems quite like science fiction. After the Moon, and after Mars, the next logical step will be to send humans to the surface of those moons. Maybe 100, 200 or 300 years from now, that could be the future.

Virtual reality

EXPLORING SPACE USING VIRTUAL REALITY

COLLABORATING WITH TECH GIANTS INCLUDING MICROSOFT, NASA IS NOW ABLE TO CONQUER THE UNIVERSE WITHOUT NEEDING TO LEAVE EARTH — AND YOU CAN COME ALONG FOR THE RIDE

Reported by Libby Plummer



Virtual reality (VR) is bringing space closer to armchair astronauts than ever before. Not only is it opening up the galaxy to those of us that will never make it beyond the Kármán line, it's also helping astronauts train for the harsh environment of microgravity and scientists for their projects.

In March 2017 a virtual recreation of the International Space Station (ISS) was launched for the Oculus Rift VR headset. Mission:ISS, which was made in collaboration with NASA, the European Space Agency (ESA) and the Canadian Space Agency, is the work of visual effects firm Magnopus, based in Los Angeles. "We started with engineering models from NASA at Johnson Space Center," Ben Grossmann, VR director of the experience and co-founder of Magnopus, tells **All About Space**. "Then we scoured the freely available images on NASA's websites for photo and video references, which our artists used when they added details. It was quite the research project because there's so much activity on the ISS, and it's so difficult to 'take inventory' regularly and get any confidence that something is where we thought it might be".

The team made a painstaking effort to get every detail exactly right, interviewing astronauts on whether there was anything missing that they expected to see. "For example, one ISS crew member pointed out to us that there was damage to one of the radiator panels that was catalogued during STS-119 that no one ever seems to

acknowledge in recreations, so we got that in there," explains Grossmann.

Aside from getting legal clearances for all the imagery and videos of astronauts, one of the biggest challenges for the effects firm was conveying the weightless experience of the orbiting lab, and translating that experience so that it would run on minimum-spec VR computers. "We spent a lot of time working on the way people could navigate with the hands by grabbing onto the station and pushing, pulling and twisting themselves through the modules," says Grossmann. "A little over 560 people have been [to space], and it's going to be a while before we can do it casually, so we wanted to give people a taste of the overall effect" he added.

While not used for formal astronaut training, Mission:ISS has been used at NASA's Johnson Space Center. According to Grossmann, when astronaut Cady Coleman was immersed in the experience, her son asked if he could have a turn, to which she replied: "No. I'm treating my homesickness."

As well as enabling people on Earth to experience the ISS, VR has also made it possible to get a glimpse of the journey back home. London's Science Museum hosts a 'Space Descent VR with Tim Peake' experience.

"In response to the landmark acquisition of Tim Peake's spacecraft, Soyuz TMA-19M, in late

Modelling spacecraft and machinery

Engineers are able to explore detailed models of spacecraft as they are being designed, allowing their design to be transformed and visualised in a way that's true to scale - something that could never be done before unless a lot of time and money was put into creating a 3D print.

HOW WE'RE USING VR FOR SPACE

Training astronauts

Before they go into space, astronauts need to be trained up for the conditions they will face. VR enables astronauts to train in a space environment, such as wearing a headset while on a weightlessness-simulating plane and in NASA's Extreme Environment Mission Operations (NEEMO).

Planning routes on Mars

Using VR, scientists are able to create a reconstruction of the Martian surface which can be worked on collaboratively - for example, to set the course and targets for NASA's Curiosity or Perseverance rover on the surface of the Red Planet.

Guiding astronauts on board the ISS

Astronauts complete complicated procedures on board the ISS. VR allows the opportunity for experts on Earth to guide residents of the Earth-orbit habitat - for example, opening hatches and putting out fires come with written procedures. With VR, a task that takes four hours could take one hour.



2016, the Science Museum Group commissioned the award-winning Alchemy VR to develop an experience that would put the visitor inside the spacecraft to experience the thrill of a high-speed descent to Earth,” Mark Cutmore, head of commercial experiences at the Science Museum, tells **All About Space**.

The VR flight, which is the Science Museum’s first-ever permanent VR fixture, is viewed using Samsung Gear VR headsets. “To achieve the extraordinary level of realism offered in the experience, the team consulted leading experts, including Tim Peake himself, and then employed the rendering power of 100 computers for a full month,” explains Cutmore.

“As well as lending his voice and on-screen presence to the experience, talking users of Space Descent VR through the stages of the flight from the International Space Station to Earth, Tim Peake consulted on the script, sharing his experience of the journey he made in June 2016 at the end of his Principia mission.”

Visitors to the museum have been impressed with the realism of Space Descent VR, says Cutmore, who explains why VR is such a useful educational tool: “The immersive nature of VR means that we can learn in a different way about the scientific story around that object or moment.” Speaking at the time of the opening, Tim Peake said: “It really is breathtaking – and that comes from someone who has spent an awful lot of time using VR systems while training for my first mission.”

As well as bringing recent missions to a wider audience, VR also enables us to relive crucial events from the history of human spaceflight, including the 1969 Moon landing. After reaching its target on crowdfunding site Kickstarter, the Apollo 11 VR experience was launched in 2016 on a number of VR platforms including Oculus Rift and Sony’s PlayStation VR. The virtual experience includes several highlights of the era-defining mission, from the Saturn V rocket down to the lunar lander at Tranquillity Base. Though not officially endorsed by NASA, it uses the American space agency’s archive footage and audio from the Command Module’s cockpit to recreate the historic journey.

There are all kinds of space-based VR apps that can easily be downloaded for viewing on basic headsets like Google’s Cardboard viewer, and even the revamped stereoscopic View-Master viewer is giving children the chance to explore a virtual version of our very own Solar System.

Not only does VR enable those on Earth to catch a glimpse of life in orbit, it’s also used to prepare astronauts for the challenges of space. NASA was

an early pioneer of VR, with its first headset dating back to 1991. The astronaut crews from Mercury, Gemini and Apollo spent more than a third of their training time packed into simulators, while crews today use VR simulations to train for their missions. One vital piece of training involves practice with a version of the Simplified Aid For EVA Rescue (SAFER) – a jet pack worn by astronauts that they can use to manoeuvre back to the ISS should they become untethered during a spacewalk.

As well as training astronauts on Earth, VR is also being used in space to carry out vital experiments. The French space agency Centre National d’Etudes Spatiales (CNES) is using one such experiment called GRASP (Gravitational References for Sensorimotor Performance: Reaching and Grasping) to look at how astronauts’ brains adapt to coordinate hand movements in microgravity. French ESA astronaut Thomas Pesquet was tasked with setting up and testing the equipment on the ISS, where it is used for tests by crew members.

The kit includes an Oculus Rift headset which has been modified for use in space to ensure that

“THE IMMERSIVE NATURE OF VR MEANS THAT WE CAN LEARN ABOUT THE SCIENTIFIC STORY IN A DIFFERENT WAY” MARK CUTMORE



Left: NASA and Microsoft engineers testing Project Sidekick HoloLens headsets during a microgravity parabolic flight

Below: The ESA’s Thomas Pesquet training with VR at NASA’s Johnson Space Center



it is not a fire risk. The headset's accelerometer cannot be used in the same way in microgravity, so researchers rely on an infrared motion-tracking system developed by the ESA to monitor movement instead. The experiment involves astronauts reaching for virtual objects to enable researchers to understand how important gravity is compared to other senses.

Maurice Marnat from the MEDES Institute of Space Medicine and Physiology in Toulouse, France, which is an affiliate of CNES, explains that on Earth the brain uses sensations caused by gravity as a reference for movement, using a football player as an example. "If I see a football coming towards me, I know it will have a specific weight, and I can predict its trajectory. Children take a long time to learn to make these predictions accurately," he tells **All About Space**. "When astronauts first arrive in space, they are like babies again. They have to learn how to move and how to integrate their visual information into their movement."

Not only could the findings help astronauts aboard the ISS - and during spacewalks where

Right: Tim Peake uses Space Descent VR to relive his Soyuz TMA-19M flight



© ESA

DESTINATION MARS

Using HoloLens, NASA is able to walk on the surface of the Red Planet and make plans to conquer it

1. Real Mars data

Looking through the HoloLens, users are able to 'stand' on Mars and look at a real surface from data gathered by Mars orbiters and the Curiosity rover. Using VR, you'll be able to stand next to the Martian spacecraft.

2. Taking a friend

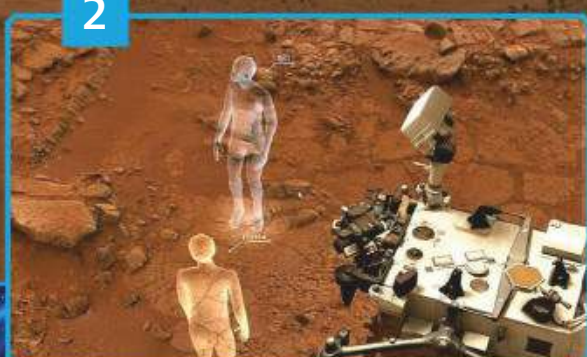
If you decide to experience the surface of the Red Planet with a friend or two, you'll be able to see them on the surface next to you as an avatar no matter where they are in the world.

3. Useful for science

Teams of scientists are able to collaborate on the surface of Mars, which makes planning the Curiosity rover's next move easy. Scientists are able to see each other as avatars and also where they are looking.

4. Walking on Mars

Scientists are able to traverse the surface of Mars, which allows them to walk up mountains and tread the same ground Curiosity has trundled along, as well as the regions that orbiters have mapped.



© NASA

Virtual reality

hand-eye coordination is extremely important - they could also eventually help scientists to better understand patients with conditions that cause a loss of balance on Earth.

Another CNES experiment will investigate the problems astronauts have with time estimation in space, which is known to be connected to microgravity's effect on the inner ear. "The goal is to quantify this effect. The VR is used only to immerse the subject in a virtual world - to disconnect them from any external information," explains Marnat.

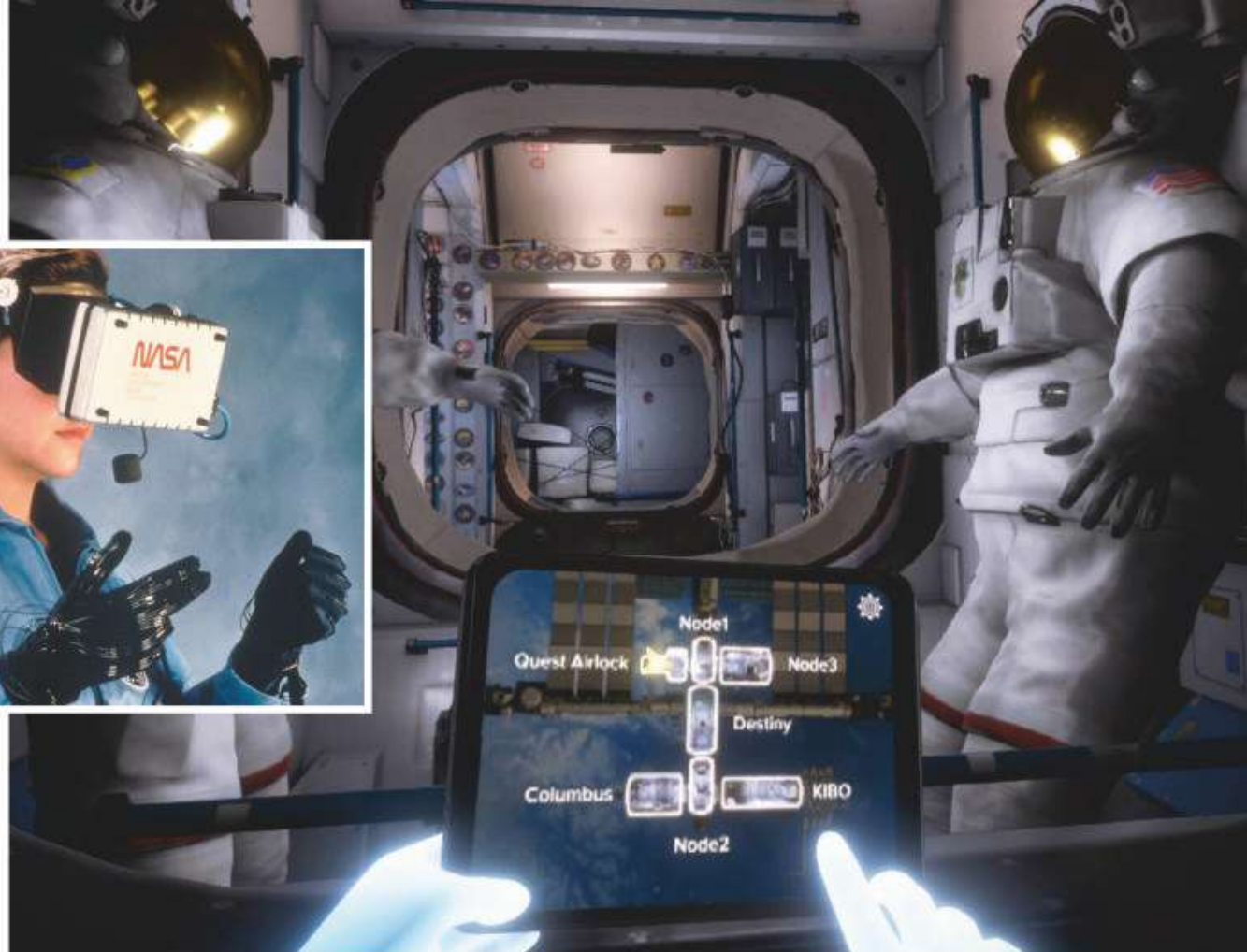
Meanwhile, a separate experiment from the Canadian Space Agency will look at the effects of reduced gravity on astronauts' perception of self-motion. "We hope to be able to build a VR community in space," explains Marnat. "VR opens the door to many more applications other than science, such as on-board training, and helping astronauts on a daily basis as a countermeasure against confinement".

And it's not just VR that's blurring the boundaries between Earth and travelling in space. Augmented reality (AR), where computer graphics are superimposed over a real-world view, is also becoming more popular, but it's mixed reality (MR) - a combination of VR and AR - that could really be a game changer. One of the best known examples of an MR device is Microsoft's HoloLens.

In December 2015 NASA launched a pair of HoloLens headsets to the ISS as part of Project Sidekick. The devices were originally intended to arrive earlier, but the first batch were blown up when SpaceX's CRS-7 Falcon 9 resupply rocket exploded shortly after take-off in June 2015. In 'Remote Expert Mode' the HoloLens enables ground operators to be able to see what a crew member sees via messaging platform Skype, providing real-time guidance and annotations to guide the astronaut through a task. Previously they would have had to rely on just vocal and written instructions. In 'Procedure Mode' it presents animated illustrations on top of the objects the crew are interacting with. The idea is to cut down the amount of training for future crews.

"The benefit of Project Sidekick and related AR applications is the ability for crew to operate hands-free and see their surroundings comfortably at all times," Victor Luo of NASA's Jet Propulsion Laboratory tells us.

In collaboration with Microsoft, NASA has also developed software called OnSight that enables scientists to work virtually on Mars using the HoloLens. "We take the 2D rover



images from Mars and reconstruct a 3D terrain mesh using our homegrown photogrammetry pipeline," explains Luo. "Every day the scientists on the Curiosity mission can load up OnSight and walk on the latest place on Mars. They can gather with their international colleagues in the same session and collectively make strategic science planning decisions for the operations of the rover.

"We have been developing outreach experiences with this technology to allow the general public to experience the journey of the rover as well. The most recent public release is the Destination: Mars experience that we deployed to Kennedy Space

Center Visitor Complex in 2016, which captures Buzz Aldrin in holographic form to guide the audience through three real sites on Mars."

NASA has also developed ProtoSpace, which uses the HoloLens to project images of rover mock-ups in 3D to help engineers pinpoint any potential problems in future designs.

"These technologies will allow our scientists, astronauts and engineers to immerse themselves in the data that they need at any given time," says Luo. "When we continue to explore the Solar System via robots and astronauts, we will be able to take everyone along for the ride."

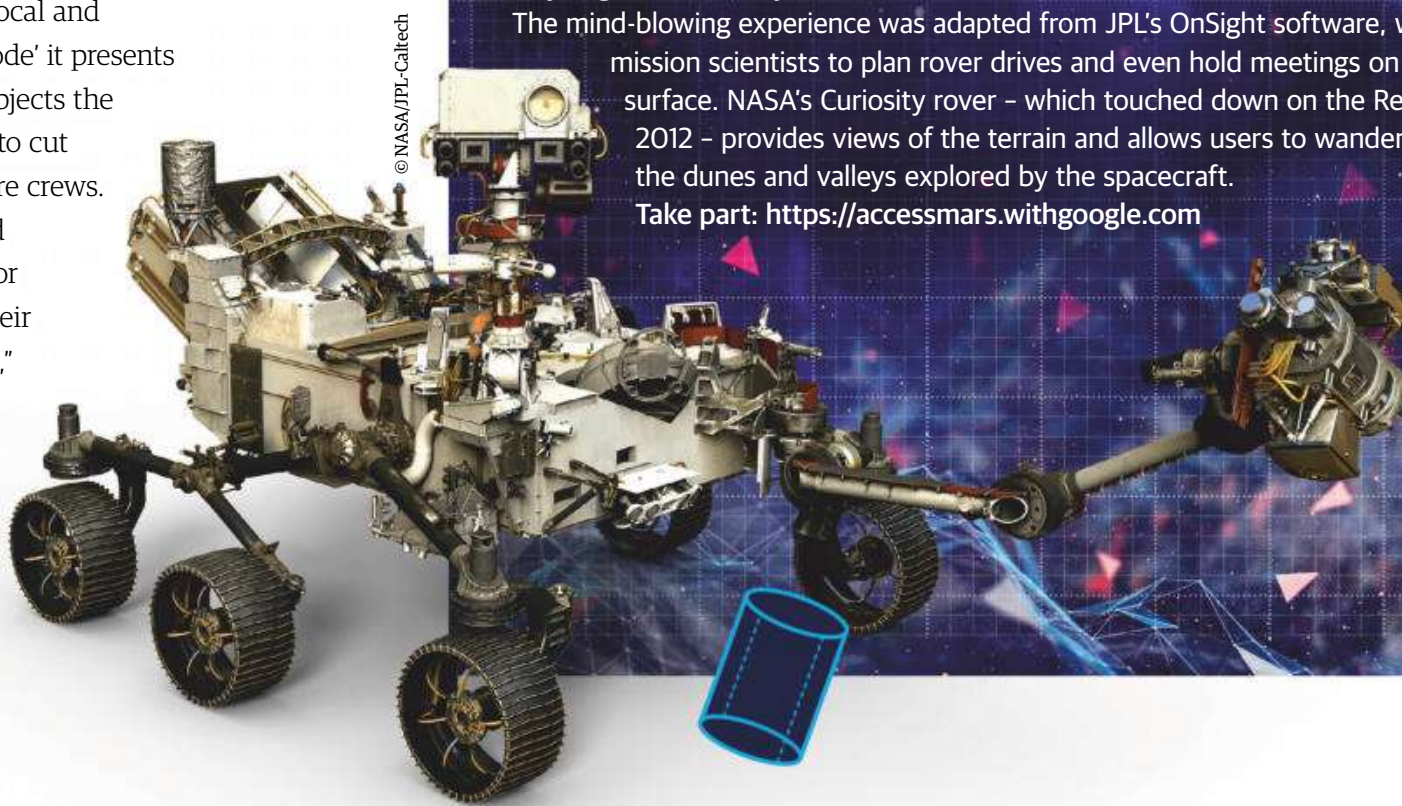
Above: Users can explore the International Space Station in VR with Mission:ISS

FOLLOW THE PATH OF A ROVER

It's now possible to track the journey of NASA's Curiosity rover as it trundles across the surface of the Red Planet by simply donning a headset wired up to an internet connection. In collaboration with Google, NASA's Jet Propulsion Laboratory (JPL) has released *Access Mars*, a free immersive experience that allows everyone to virtually explore the Martian landscape through all desktop and mobile devices as well as virtual reality/augmented reality (VR/AR) headsets.

The mind-blowing experience was adapted from JPL's OnSight software, which helps mission scientists to plan rover drives and even hold meetings on Mars' surface. NASA's Curiosity rover - which touched down on the Red Planet in 2012 - provides views of the terrain and allows users to wander through the dunes and valleys explored by the spacecraft.

Take part: <https://accessmars.withgoogle.com>



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The Hope probe will arrive in February 2021, a year which marks the 50th anniversary of the UAE's formation



USER MANUAL

Hope Mars Mission

The United Arab Emirates (UAE) is preparing a milestone venture to the Red Planet, propelling the country forward in exploration

THE SPECS

Launch: 14 July 2020 (UTC)

Arrival: February 2021

Target: Mars

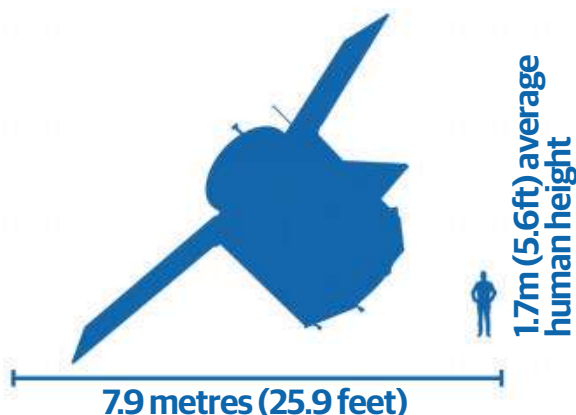
Launch rocket: Mitsubishi Heavy Industries H-IIA rocket

Operators: Mohammed bin Rashid Space Centre

Planned mission duration: One Martian year (approximately two Earth years)

Height: 2.9 metres (9.5 feet)

Diameter: 2.4 metres (7.9 feet)



The United Arab Emirates Space Agency (UAESA) was established in 2014 and has evolved exponentially over the last six years. Fast forward to July 2020 and the agency is now preparing to launch its fourth satellite and its first spacecraft to another planet. This mission was dubbed the Emirates Mars Mission, and was later called the Hope Mars Mission. There are many monumental milestones sewed into this mission as the UAE looks to announce itself as a prominent presence within the space exploration industry and in future global scientific efforts.

The nation has been extremely driven in its post-oil economy, which has also been seen in the rapid growth of Dubai's infrastructure. This is the same drive that is bringing its space agency along leaps and bounds. The country's main space centre, the Mohammed bin Rashid Space Centre (MBRSC), was established in 2015, and it has since been the workshop for the Hope Mars Mission. This mission will become the first planetary science mission led by an Arab-Islamic country, which the UAE hopes will be the first step in a long and fruitful period of science and exploration. When Hope arrives at Mars in 2021, this event will also coincide with the golden jubilee - or 50th anniversary - of the founding of the UAE.

With this in mind, the nation and its space agency wanted to make this a mission that would have a benefit to all members of science and offer something original. The UAESA reached out to other space agencies and institutions and has created a state-of-the-art weather satellite in collaboration with the University of Colorado Boulder, the University of California, Berkeley, and Arizona State University, all of the United States.

The satellite will carry three scientific instruments - a camera, an infrared spectrometer and an ultraviolet spectrometer - that will paint a clearer picture of the Martian atmosphere, its different layers and how it has evolved from a thicker atmosphere capable of protecting global oceans billions of years ago to the thin, exposing atmosphere that is witnessed today.

The first experiment is the Emirates eXploration Imager (EXI). This multi-band - visible and ultraviolet - high-resolution camera aims to image the atmosphere and surface of Mars to a spatial resolution of less than eight kilometres (five miles), in order to measure dust, water ice and ozone abundance in the atmosphere. This camera will return beautiful images of the Red Planet through the lens of a historic Arab mission, giving us stunning views of the planet next door.



Anatomy of the UAE's first Mars mission

There are three main instruments on board to investigate the Red Planet, but there is so much more required to ensure a successful spacecraft

5 Solar panels

The top platform is fixed with three solar panel wings, providing the spacecraft with 600 watts of power on Mars. The spacecraft needs 477 watts to operate.

1 Emirates eXploration Imager (EXI)

This 12.6-megapixel camera has three ultraviolet and three visible filters that will return excellent colour images of the Martian surface and study the planet's dust, water-ice clouds and ozone.

4 High-gain antenna

The 1.5-metre (five-foot) diameter high-gain directional dish antenna is mounted on the top deck of the spacecraft and will relay communications back to Earth.

6 Star tracker

This component will identify constellations in relation to the Sun and help determine the spacecraft's position and orientation.

2 Emirates Mars Ultraviolet Spectrometer (EMUS)

The far-ultraviolet spectrometer will characterise the escape of oxygen and hydrogen from Mars and study the behaviour of hydrogen, oxygen and carbon monoxide in the thermosphere and exosphere.

3 Mars InfraRed Spectrometer (EMIRS)

The infrared spectrometer will characterise the dust and water-ice clouds, track the Martian water cycle and Mars' thermal state and determine the boundary conditions for the lower atmosphere.

7 Honeycomb structure

The Hope probe flaunts a unique spacecraft design. It's made up of honeycomb aluminium panels with composite face sheets.

8 Thrusters

Any manoeuvring and altitude adjustments will be done with the help of eight five-Newton reaction control system thrusters. The spacecraft's speed is helped by six 120-Newton thrusters.

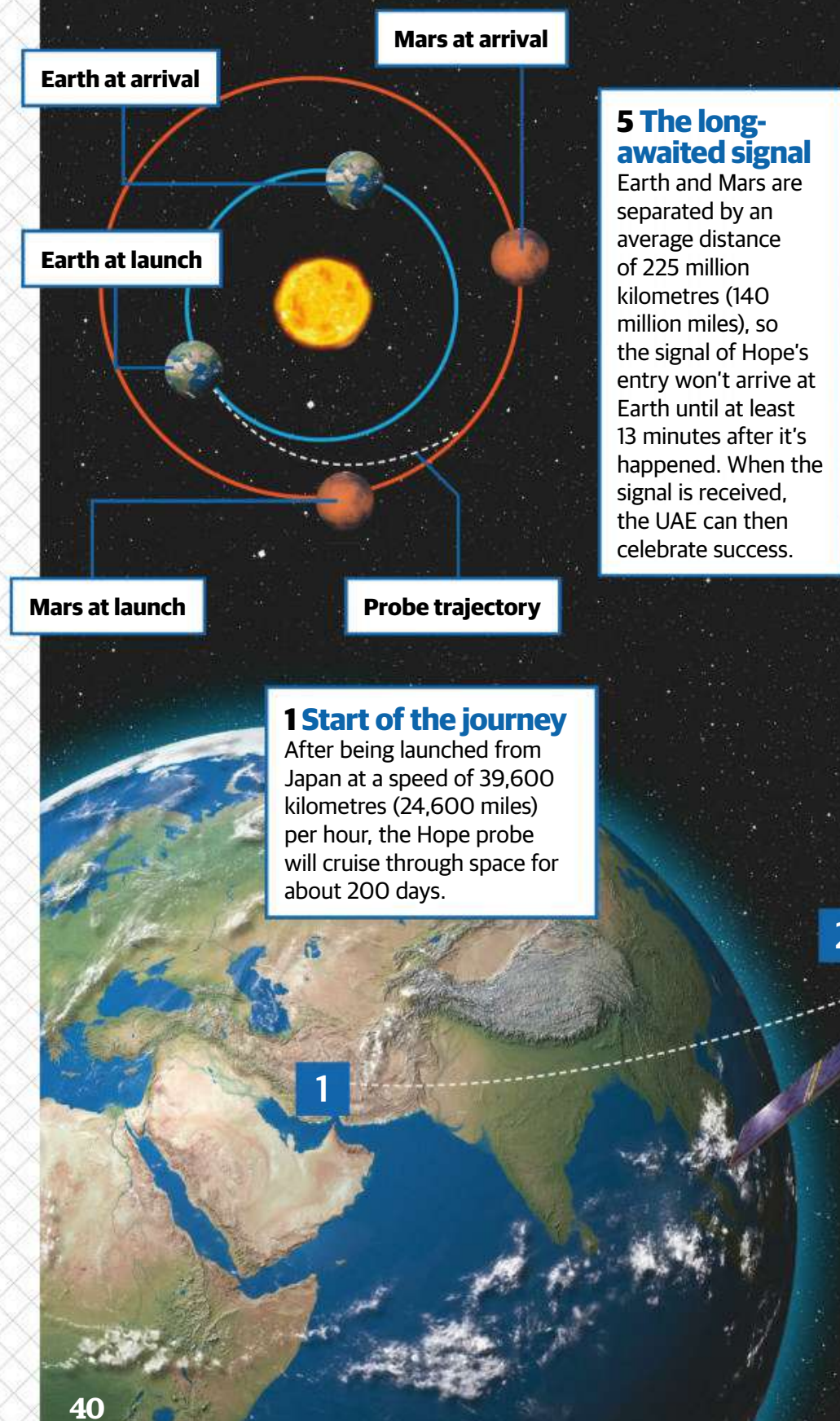


Left:
Transporting
the Hope
probe from
Dubai to Japan
took 11 hours

The other two experiments consist of the Emirates Mars InfraRed Spectrometer (EMIRS) and the Emirates Mars Ultraviolet Spectrometer (EMUS). The EMIRS experiment, in collaboration with Arizona State University, will track temperature patterns as well as identifying the ice, water vapour and dust configuration in the atmosphere. As for EMUS, this experiment will monitor changes in the thermosphere, which is one of the outermost layers of an atmosphere. This will study how hydrogen and oxygen is lost to space via the thermosphere. It will also monitor the exosphere and how it changes with the seasons.

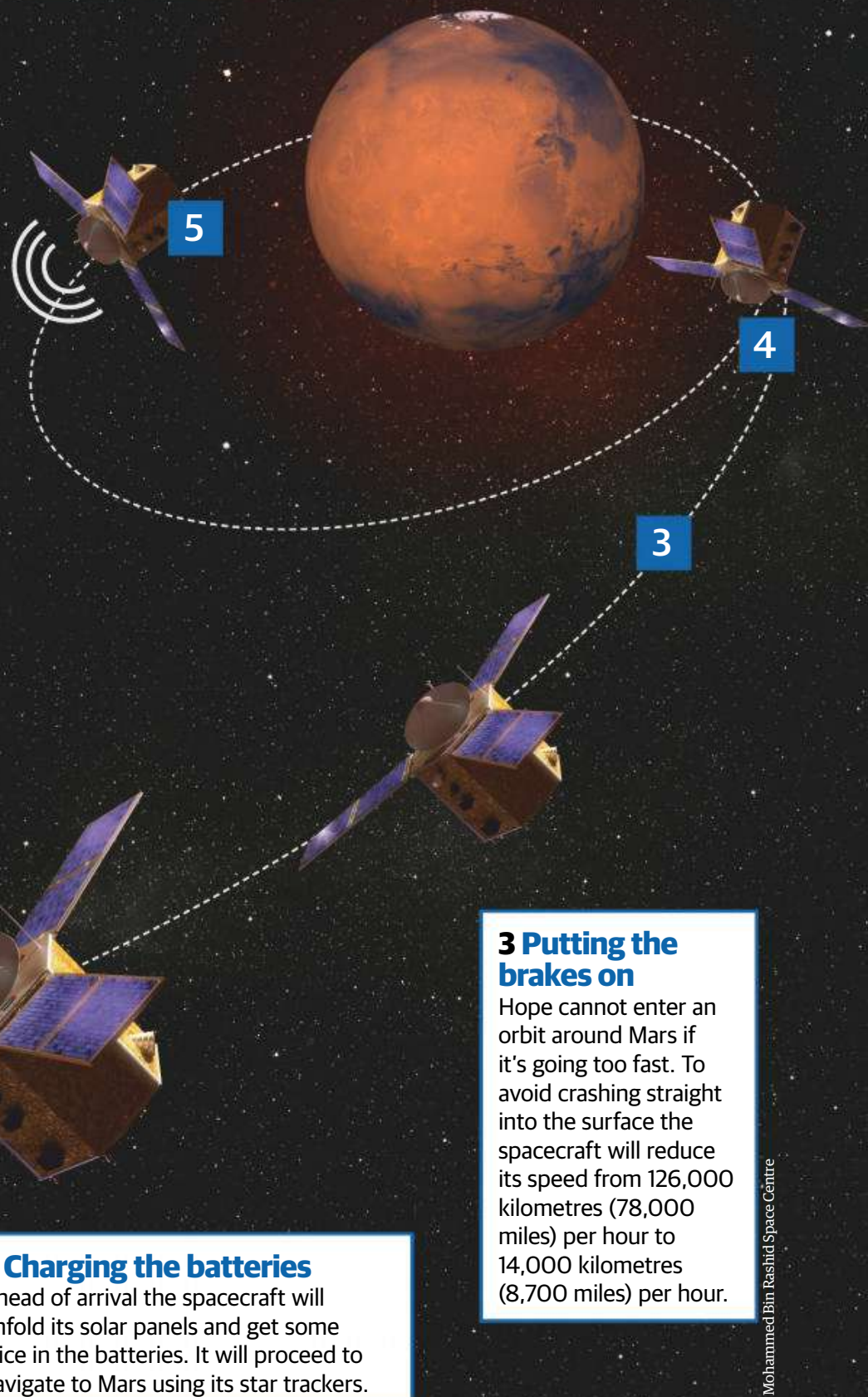
At the time of writing the spacecraft is due to launch from Japan's Tanegashima Space Center,

How Hope will make its way to Mars



4 Entering an elliptical orbit

After a successful orbital insertion the spacecraft will fly above the surface of Mars at altitudes ranging between 22,000 and 44,000 kilometres (14,000 and 27,000 miles).



riding on a Mitsubishi Heavy Industries H-IIA rocket, on 14 July 2020 (UTC). This has not been smooth sailing by any means, especially during the midst of a global pandemic. "The challenges overcome by the Hope team amidst the global pandemic confirm the UAE mission's commitment to achieve the impossible," says Sarah bint Yousif Al-Amiri, minister of state for advanced sciences and the mission's deputy project manager. "It is a mentality that has now been embedded within the current and future generations. This mission embodies the nation's aspirations, sends a positive message to the world and demonstrates the importance of carrying on unabated despite barriers and challenges."

The UAE has a tremendous amount of hope for this appropriately named mission. It has been referred to as the "Arab world's version of President John F. Kennedy's moonshot" by Yousef Al Otaiba, the UAE's ambassador to the US. By this he means that it will inspire a new generation of scientists, astronomers, geologists, astrobiologists and so many more in the same way the Apollo missions have inspired our current crop of outstanding minds. In fact, the UAE has set out on an outrageously ambitious endeavour that it refers to as the 'Mars 2117 project'. The overall aim is to pioneer the first inhabitable human settlement on Mars by the year 2117 - this will begin with the science and collaboration brought about by the Hope mission.

TOP TECH

Emirates eXploration Imager (EXI)

This will generate the most visually spectacular results, which are likely to be shared across the internet for all to see. A lot of successful missions share popular high-resolution images, such as NASA's Mars Reconnaissance Orbiter and its High Resolution Imaging Science Experiment (HiRISE) camera and the Juno spacecraft's JunoCam.

The Hope probe's EXI can operate in two bands, visible and ultraviolet, and can image the surface of Mars at a resolution of 2.2 kilometres (1.4 miles) per pixel at its closest point and 4.9 kilometres (three miles) per pixel at farthest.



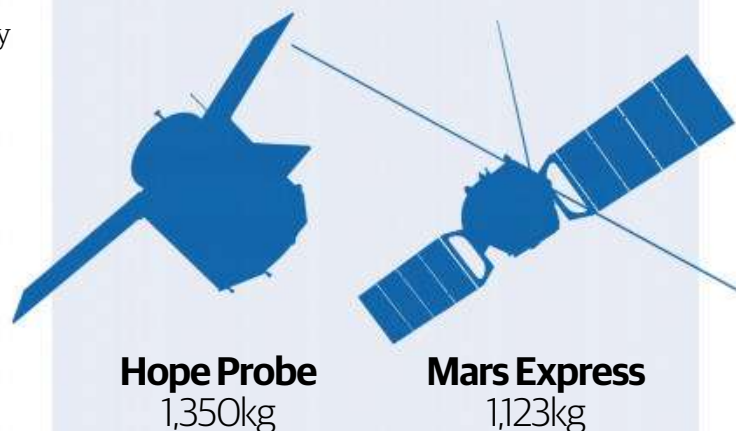
© MBRSC

Head-to-head Hope Probe vs Mars Express

In terms of dimensions the Hope probe is roughly a metre (3.2 feet) larger in both height and width, and is heavier by about 227 kilograms (500 pounds). Although their solar panels are presented differently, they both have an aluminium honeycomb structure.

The UAE made a major effort in designing a spacecraft unlike any other, and decided Hope would be a Mars weather-orientated mission.

Mars Express does share similar ambitions though, as its main objective is also to map the planet's atmosphere and climate, as well as to study the planet's structure; its mineralogy and geology and to search for traces of water.



Vital statistics

55
hours

=

The time taken for Hope to complete one orbit around Mars

6
years

=

The time it took the UAE Space Agency to develop the Mars mission

2025

=

The mission could be extended by up to two years

1.6 Mbps

=

The data bandwidth at Mars' closest point to Earth

3.5
billion
years ago

=

Years since the Martian atmosphere was thick enough to allow for surface oceans

HOW TO...

Build a human settlement on Mars by 2117

1 Starting with Hope

Hope is not just about sending a satellite to the Red Planet to study its atmosphere and climate. The UAE intends for this mission to be the fuel that propels the nation to a new frontier. This mission is just the beginning.



© Government of Dubai Media Office

2 Continuous collaboration

Space exploration is rarely an individual endeavour. There is help from around the globe, and these are the kinds of relationships the UAE is looking to build. It's already started by creating Hope with the help of US-based institutions.



© Mohammed bin Rashid Space Centre

3 Establishing a roster of astronauts

On 25 September 2019 the UAE saw Hazzaa Ali Almansoori visit the International Space Station, becoming the first Emirati astronaut in history. This was seismic in terms of the UAE's plan to establish an astronaut program.



© NASA

4 Endgame: Mars 2117

The UAE hopes to build the world's first sustainable habitat on Mars. In 2017 Sheikh Mohammed bin Rashid Al Maktoum, vice president and prime minister of the UAE, directed the MBRSC to lead this effort.



© Government of Dubai Media Office

10

STARS DUE TO GO SUPERNOVA

Meet the stellar suspects most likely to
explode, sending out planet-destroying
shock waves

Reported by Ben Evans

Since ancient times supernovae – the explosive deaths of stars – have been observed and recorded with fascination. Chinese astronomers described an event in 185 CE as resembling a large bamboo mat in the sky and noted that its five colours were “both pleasing and otherwise”. Almost a thousand years later in 1006 CE Islamic scholars witnessed a spectacle three times the apparent size and 16 times the brightness of Venus, which may also have been recorded in Native American petroglyphs.

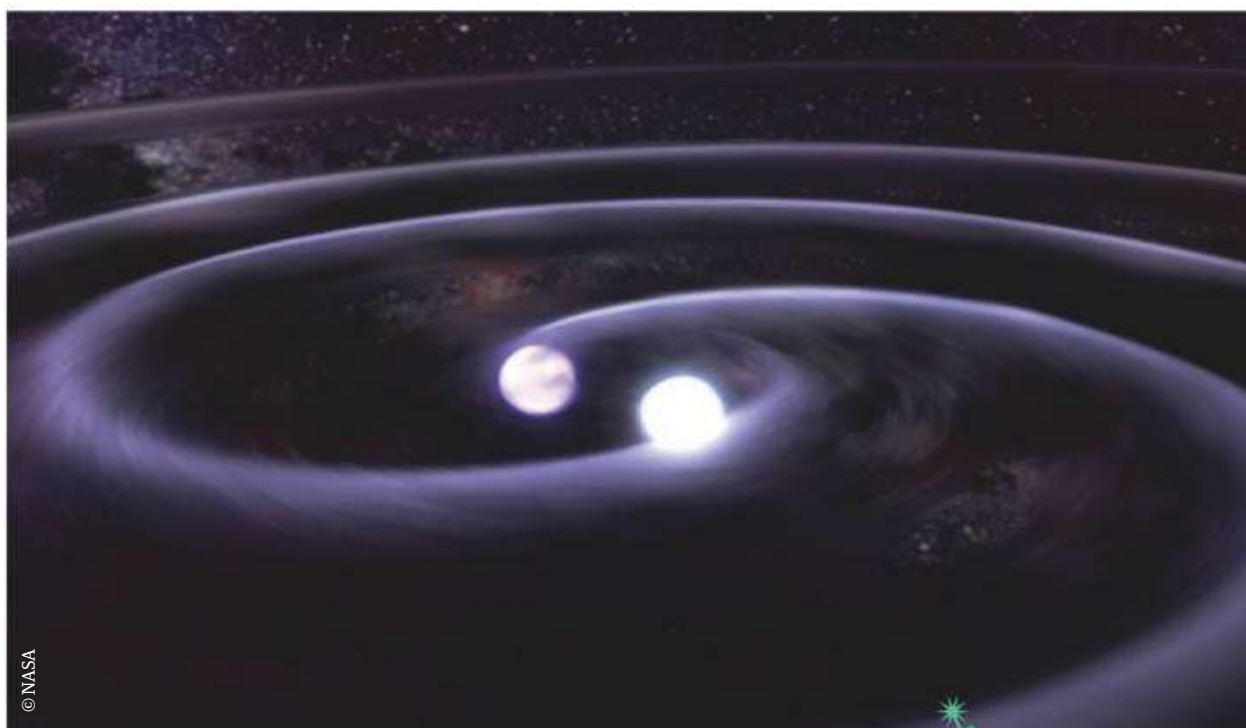
In 1604 astronomer Johannes Kepler directly observed the most recent supernova to have originated within the Milky Way. It originated 20,000 light years away and was so bright that it could be seen during the daytime for three weeks.

Within our own galaxy, only five supernovae have been observed with the naked eye in the last millennium. Others have been recorded telescopically – including SN 1987A in the Large Magellanic Cloud.

It's been estimated that about one or two of these events occur in any single century. Yet the vast distances between the stars and the immense amount of time required for their light to reach us mean that in most cases we are only able to see the stars as they were hundreds or even thousands of years ago.

Although we know which stars have almost exhausted their nuclear fuel reserves and are approaching the end of their lifetimes, we can only surmise when they will ‘go supernova’. Ten candidates of varying ages and sizes are known to be close to death. They may have already exploded, and the light from their agonised death throes may still be hurtling across the universe at 300,000 kilometres (186,000 miles) per second to someday reach us. We may not see a supernova in our lifetime... or we could see one tomorrow.

Right: These dense white dwarfs orbit each other every 321.5 seconds. It's the fastest moving binary system ever found



1 HM Cancri

Making ripples in the fabric of space-time



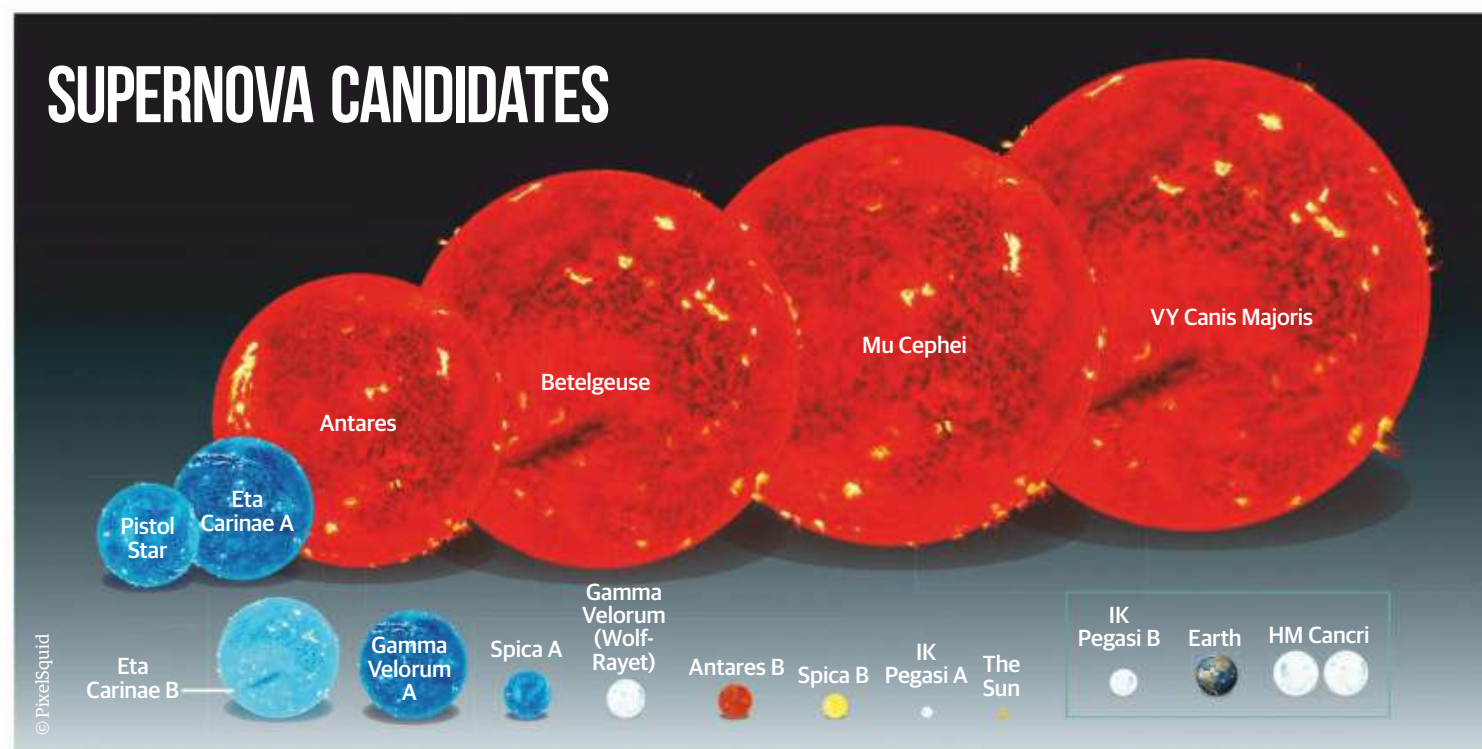
Over 16,000 light years away, a pair of dense ‘white dwarfs’ – tiny stellar remnants with masses equivalent to that of the Sun bundled into diameters broadly the size of Earth – circle each other every 321.5 seconds.

In doing so they are the fastest moving binary system ever found. Separated by approximately 80,467 kilometres (50,000 miles), a fifth of the distance between Earth and the Moon, the half-solar-mass X-ray binaries of HM Cancri whirl around one another at 1.4 million kilometres (890,000 miles) per hour. As each day passes their orbit brings them closer, raising the probability that they will eventually merge.

When they do merge, it is likely that HM Cancri will produce a Type Ia supernova. This type of supernova occurs in binary systems with one or more white dwarfs, which although little more than the ‘corpses’ of deceased stars remain capable of further fusion reactions and can still pack an energy-laden punch if their temperatures rise high enough. In fact, the HM Cancri duo, containing highly condensed helium, carbon and oxygen, are so close together that mass flows from one to the other.

First identified as a weak X-ray emitter by Germany's ROSAT craft in 1999, HM Cancri may also be one of the strongest sources of gravitational waves ever observed.

SUPERNOVA CANDIDATES



2 Gamma Velorum

An explosion of multiple stars

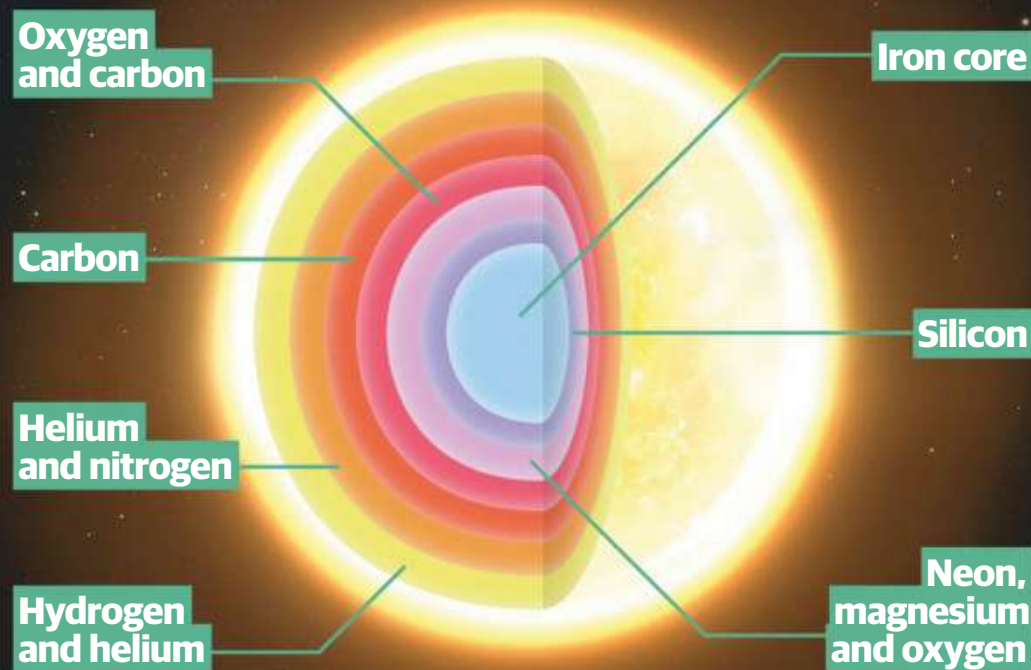


Gamma Velorum is not one star, but at least four or even six. Known by its Arabic name of 'Suhail' or as 'Regor' in honour of Apollo 1 astronaut Roger Chaffee, its brightest members are the binary pairing of Gamma Velorum A.

Situated 1,096 light years from us, this duo hosts a blue supergiant and the nearest known example of a 'Wolf-Rayet' star. Wolf-Rayet stars are characterised by high

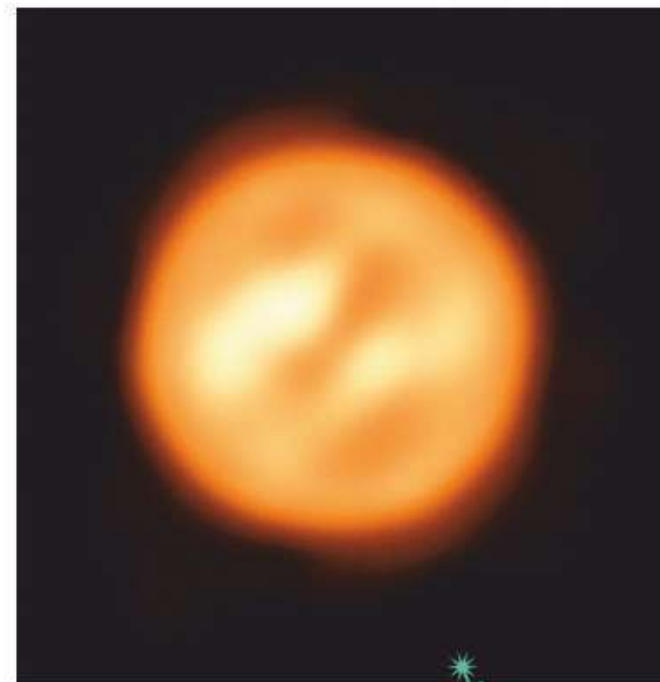
stellar winds and extreme surface temperatures and tend to lose mass quickly, usually within a million years or so. In Gamma Velorum A's case, the Wolf-Rayet star may have already stripped itself down from 40 solar masses to its present state of nine solar masses. Although it is probably no older than 5.5 million years, it is at an advanced state of age and is expected to meet its end as a Type Ib or Ic supernova.

INSIDE A WOLF-RAYET STAR



© Tobias Roetsch

Right: A reconstructed view of the surface of Antares A, imaged by the Very Large Telescope (VLT)



© ESO

3 Antares

Mars' rival



When Antares reaches the end of its life, it could be as bright as a full Moon and perhaps visible from Earth for several months. At 883 solar radii, it is smaller than Betelgeuse but has a similar surface temperature and mass. Antares is at the heart of the constellation Scorpius and is around 12 million years old. It will likely go supernova in a few hundred thousand years.

Named by the ancient Greeks for its similar colour to Mars, 'Antares' means the rival of Mars, using 'Ares', the Hellenic name for the Roman god of war. Located around 550 light years from Earth, Antares is joined by a smaller and dimmer companion, Antares B. Both, however, greatly outshine the Sun. The end of Antares could have already begun, or it may take the next few hundred millennia for it to go supernova.

4 IK Pegasi

The double star

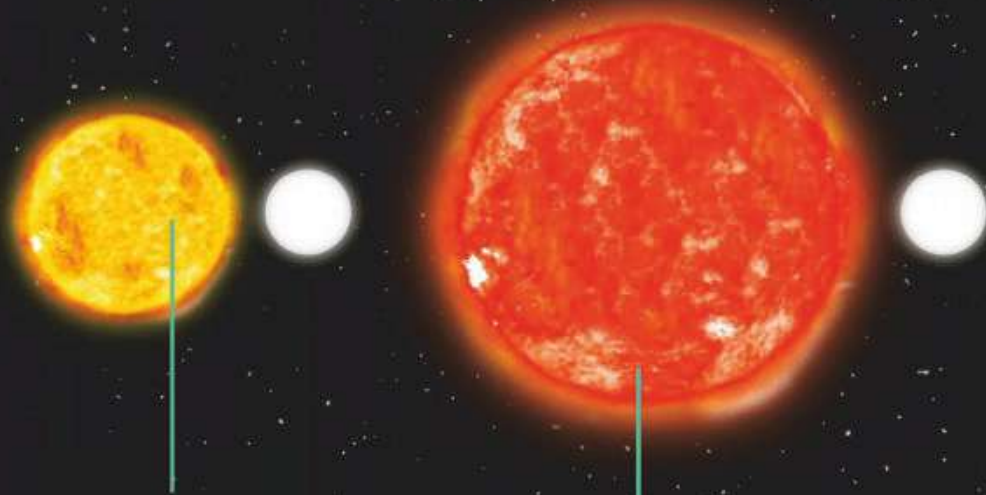


Perhaps the closest candidate for a supernova explosion, IK Pegasi is a binary system that resides about 150 light years from our Sun.

IK Pegasi A is a main sequence star that undergoes rapid pulsations in luminosity, triggered as its outer atmosphere optically thickens in response to the partial ionisation of elements. Temperatures rise, causing the atmosphere to expand, and when ionisation decreases it contracts.

Its companion, IK Pegasi B - from which it is separated by 30.5 million kilometres (19 million miles) - is a massive white dwarf. When IK Pegasi A moves off the main sequence and expands in later life to become a red giant, its companion may begin to siphon material from its surface and grow in solar mass. But IK Pegasi A is still barely 1.7 solar masses and has a long way to go before it reaches the eight-solar-mass minimum needed to go supernova, known as the Chandrasekhar Limit. As for IK Pegasi B, it is currently a large white dwarf and stands at 1.15 solar masses.

HOW IK PEGASI WILL EXPLODE



An explosive pair

The IK Pegasi system consists of a main sequence star and a massive white dwarf.

Moving on

IK Pegasi A moves off the main sequence and becomes a red giant.

© Tobias Roetsch

5 Eta Carinae

The repeat detonator



Despite early claims that the Pistol Star was the most luminous star ever found, it's actually three-times dimmer than Eta Carinae. The latter was originally recorded at fourth magnitude, but in a 20-year event called the 'Great Eruption' it dramatically blazed to become the brightest star in the sky. It subsequently dimmed, brightened, dimmed and then increased in luminosity again from the 1940s. Today it sits at magnitude +4.3.

This changeable luminosity was triggered by Eta Carinae's ejection of the Homunculus Nebula, a cloud of ionised hydrogen whose light reached Earth in 1841. Condensation of dust from the nebula is thought to have been responsible for this cyclic brightening and dimming. Eta Carinae is 5 million times more luminous than our Sun. It was believed to be one of the most massive stars, but in 2005 it was found that it was actually a binary system.

Its primary may have reached 150 to 250 solar masses in its youth, but has sustained one of the highest rates of mass loss ever recorded for a star. Eta Carinae's extreme luminosity and low gravity seem to have caused this loss, and it is believed that it shed ten to 20 solar masses in the Great Eruption. Its primary could go supernova tomorrow, or thousands of years from now.

Right: Orbiting every four days, Spica's binary members cannot be split with a telescope alone

"IT DRAMATICALLY BLAZED TO BECOME THE BRIGHTEST STAR IN THE SKY"

Exploding stars



6 Spica

Virgo's supernova

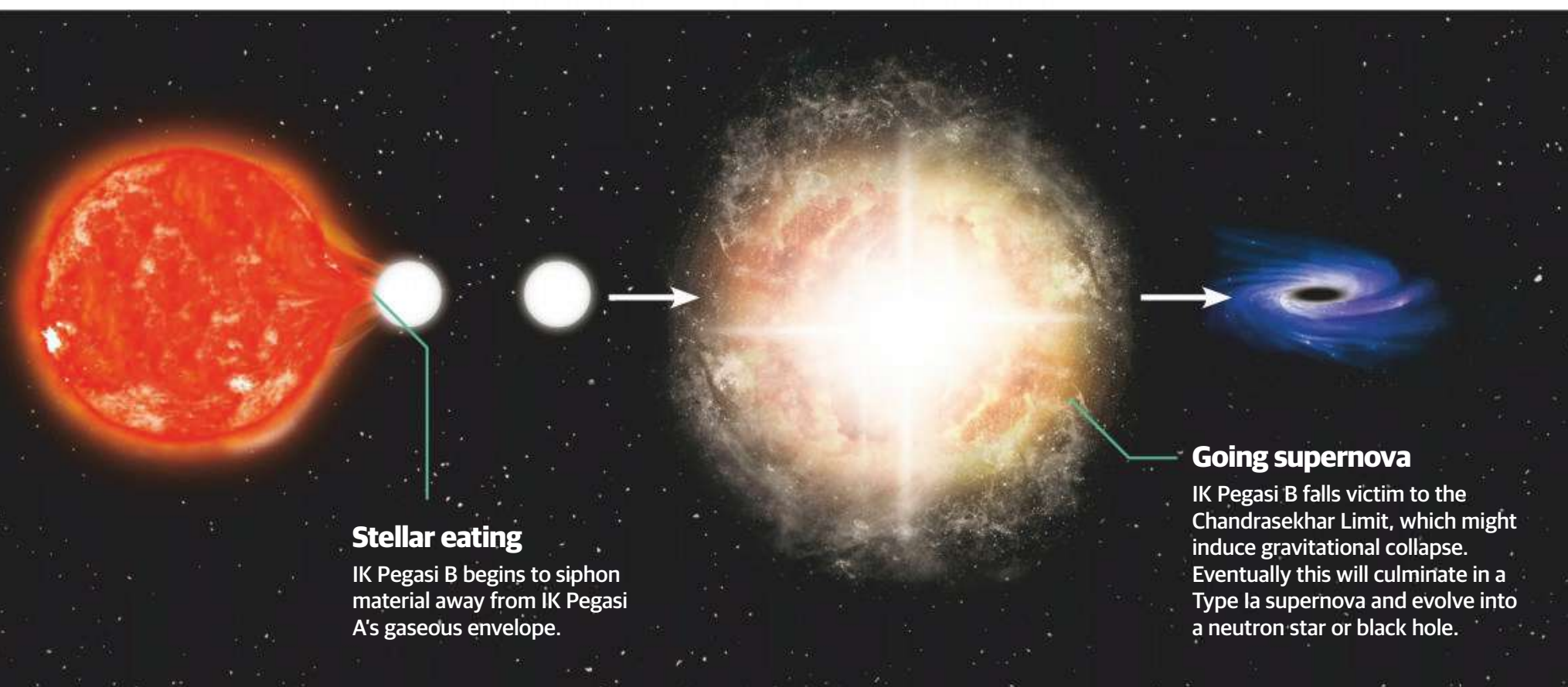


Deep in the constellation of Virgo lies the binary system of Spica: a pair of stars so close together that neither is spherical, but gravitationally distorted and egg-shaped. Separated by just 17.7 million kilometres (11 million miles) - a tenth of the gap between Earth and the Sun - the brighter 'primary' and its smaller, dimmer companion orbit one another every four days. They cannot be seen separately through a telescope and can only be resolved by spectroscopy and analysing minute variations in magnitude.

The blue-white Spica has been observed for thousands of years, with some ancient Egyptian temples oriented to face it. Only in modern times has it been possible to discern its nature as a binary system, and lunar occultations have revealed that Spica actually comprises of five objects. But for the purpose of supernova-spotting, Spica's primary takes centre stage.

It's a rapidly rotating blue giant variable star about 10.5 times as massive as the Sun. Coupled with temperatures as high as 22,127 degrees Celsius (39,860 degrees Fahrenheit) - four-times hotter than the Sun's visible surface - and a luminosity 12,100-times greater than our own star's, Spica's primary is in pole position to become a Type II supernova in a few million years from now.

© ESO



Stellar eating

IK Pegasi B begins to siphon material away from IK Pegasi A's gaseous envelope.

Going supernova

IK Pegasi B falls victim to the Chandrasekhar Limit, which might induce gravitational collapse. Eventually this will culminate in a Type Ia supernova and evolve into a neutron star or black hole.

Below:
Betelgeuse
is the largest
known star
and is under
10 million
years old



A GIANT'S EXPLOSION FROM EARTH



1 From Earth, Betelgeuse forms the right shoulder of Orion, the Hunter. Although it's young, it has progressed rapidly through its stellar evolution and is close to going supernova.



2 The sheer magnitude of the death of Betelgeuse - one of the largest known stars - will make itself apparent in Earth's skies. It should remain visible for several months.



3 When the light from its demise reaches us after travelling for 642 light years, Betelgeuse will greatly outshine the Moon in our night sky.

7 Betelgeuse

The explosion visible from Earth



Famed for its size, changeable magnitude, pulsating shape and a mispronounced name, the red supergiant Betelgeuse may have already gone supernova. It lies 642 light years away, so we might not know about it for centuries, but to our descendents it will greatly outshine the Moon in the night sky and will remain visible for months before gradually fading away.

Betelgeuse forms the right shoulder of the constellation Orion and is under 10 million years old; it's a toddler in stellar terms. But the cool, slowly rotating Betelgeuse started life at 15 to 20 solar masses and evolved rapidly.

Hundreds of times younger and larger than the Sun, it has probably already exhausted the hydrogen in its core, and in 2014 it was suggested that it might be consuming its carbon and oxygen reserves. It will then burn higher elements and could explode within 100,000 years, ending its life as a feeble neutron star.

The key to understanding Betelgeuse's fate is to establish why it loses so much mass. As it fuses higher elements, its bloated atmosphere expands and its surface gravity weakens, shedding a million times more mass per year than the Sun. Rather than a solar wind, Betelgeuse pumps out a hurricane of giant plumes. A multi-layered pulsating 'shell' of ejected material lingers around the star and might be responsible for a 15 per cent contraction in its apparent size. Astronomically speaking, Betelgeuse's doomsday is close. And the effect on our descendents? Comfortingly, it is too far away to cause Earth any harm.

8 Pistol Star

The mysterious supernova



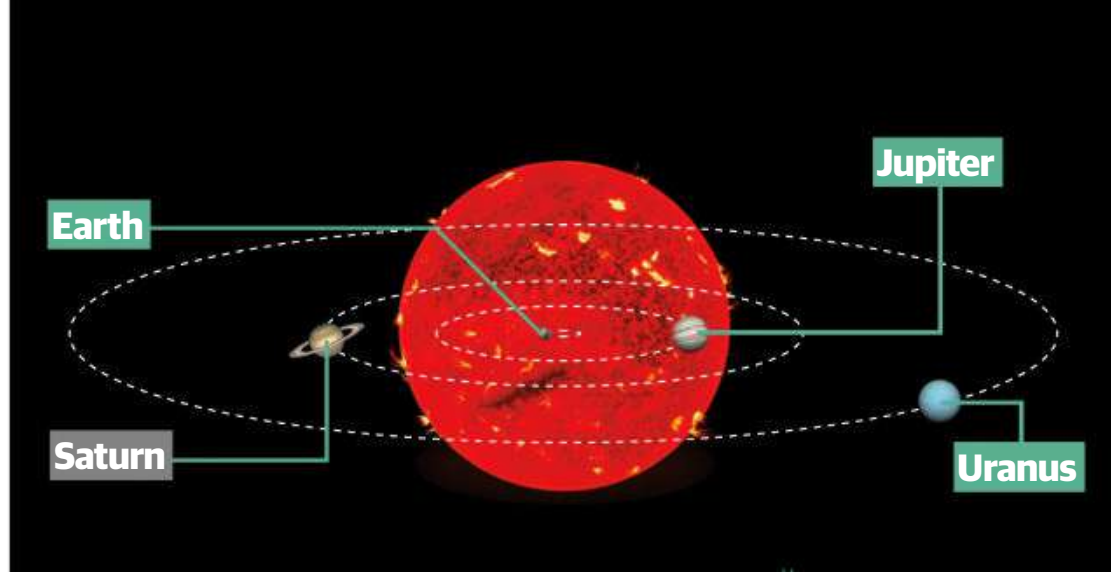
Hidden from view by a cloak of interstellar dust, the Pistol Star is a very mysterious object. Observed by Hubble in the 1990s, this highly luminous blue hypergiant is 25,000 light years from Earth, close to the Milky Way's centre. In just 20 seconds the Pistol Star radiates as much energy as our Sun does in an entire year.

At the time of its birth it is thought to have already attained somewhere around 200 solar masses, although much of this was lost in a sequence of violent eruptions. These ejected upwards of ten solar masses of expanding gaseous material in a pair of titanic outbursts some 4,000 and 6,000 years ago. With a current radius over 300 times that of the Sun, the Pistol Star is currently thought to be about 275 times as massive.

It will continue to lose material until its core is exposed. By burning a figurative candlestick at both ends - its surface temperature is 11,527 degrees Celsius (20,780 degrees Fahrenheit) - the Pistol Star will meet a rapid, fiery end in a supernova within 3 million years. Alternatively it might end its days as a super-luminous 'hypernova', which could serve as a progenitor of long-duration gamma-ray bursts.

Above: If VY Canis Majoris was at the centre of our Solar System, it would swallow up the four inner planets

Below: Such a large star will undoubtedly create fantastic stellar fireworks after it depletes its remaining fuel



9 VY Canis Majoris

The big bang



At 1,420 solar radii, VY Canis Majoris is one of the ten largest stars we know about. Before its radius was determined by the European Southern Observatory's Very Large Telescope, it was theorised that VY Canis Majoris might even be as big as 2,100 solar radii. This red hypergiant resides in the constellation of Canis Major, about 4,500 light years away from us.

With recorded observations dating back more than two centuries, astronomers have long been aware of its crimson hue and changeable magnitude. It was theorised that it was a multiple star system, but more recent imaging has

revealed bright concentrations within a vast surrounding nebula and that it has no stellar companions. Hubble data has revealed that this nebula is structurally similar to at least one yellow hypergiant, prompting suggestions that it might follow this evolutionary route before eventually becoming a Wolf-Rayet star.

It has experienced many localised eruptions, forming loops, arcs and knots of material as it approaches the end of its life. Today VY Canis Majoris has probably shed around half of its mass as it continues to exhaust its nuclear fuel and draws inexorably closer to a likely supernova.

10 Mu Cephei

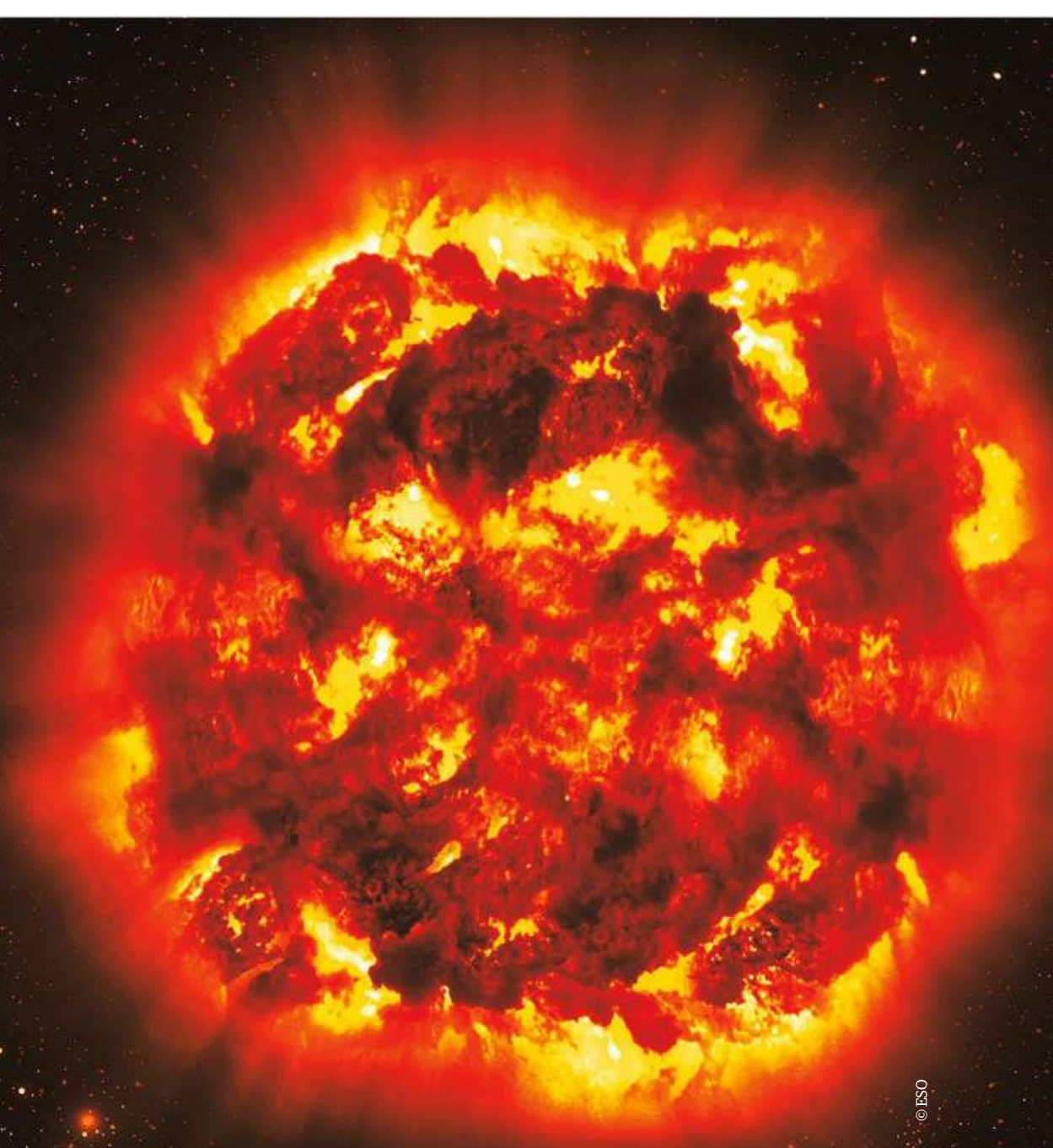
The garnet explosion



The red supergiant Mu Cephei is one of the largest stars known to humanity. With a luminosity around 100,000-times greater than our Sun, and with a radius pegged at around 1,260 solar radii, its rich reddish hue led the 18th-century astronomer William Herschel to describe its "very fine deep garnet colour", which he likened to the red giant Mira. As a result Mu Cephei very quickly earned the moniker of 'Herschel's Garnet Star'.

A 10-million-year-old variable star, records of its changeable magnitude - which varies between +3.4 and +5.1 - have been maintained continuously for more than 130 years, although its distance has been tentatively determined in the range of 6,000 light years. Mu Cephei may be surrounded by a vast 'shell', perhaps as much as 3,000 years old, which extends outward to a distance of about one-third of the star's radius. This dusty shell is known to be somewhat asymmetrical in shape, perhaps torus-like, and Mu Cephei is thought to be losing several solar masses worth of material each year.

Despite its relative youth, Mu Cephei has already exhausted its hydrogen supply and is in the process of fusing helium into carbon. As is the case with many large stars, the conversion of elements to iron will precipitate the final cataclysmic collapse of the core, a spectacular supernova leaving a feeble remnant of what once was. It seems plausible that Mu Cephei will die in a Type II supernova - rapidly collapsing and violently exploding within a million years - although the form its remains will subsequently take is unknown.



PROJECT RAMA

A Californian company wants to turn asteroids into autonomous spacecraft in order to mine their surfaces before relocating them in space

Every year NASA selects a range of speculative projects through its Innovative Advanced Concepts (NIAC) program. It is through this program that Made In Space (MIS) has received an award for Project RAMA. The project is partly named after an Arthur C. Clarke story where an empty, automated colony ship built in an asteroid arrives in the Solar System - the initials in this case stand for Reconstituting Asteroids into Mechanical Automata.

Based in Mountain View, California, MIS was founded in 2010 with the aim of using additive manufacturing - or 3D printing - to dramatically reduce the costs of operations in space. In additive manufacturing a supply material, often a plastic filament or metal dust, is fused together into objects rather than cut out of a bigger piece. For launches from Earth this would save volume and mass, and space missions would be able to print spare parts as needed. MIS supplied a printer to the International Space Station in order to test the process in microgravity.

But MIS' ultimate goal, which would enable mass settlement in space, is to employ additive manufacturing with materials sourced in space; this is where RAMA comes in. Not only would it save the cost and difficulty of launching stuff from Earth - we'd only need to send people and

1 Asteroid mining

Robotic mining equipment would need to be part of the RAMA system in order to extract raw materials from an asteroid.

2 Space settlement

Using space-based materials would transform space exploration, opening up the Solar System to us and enabling the construction of space settlements.

3 Propulsion

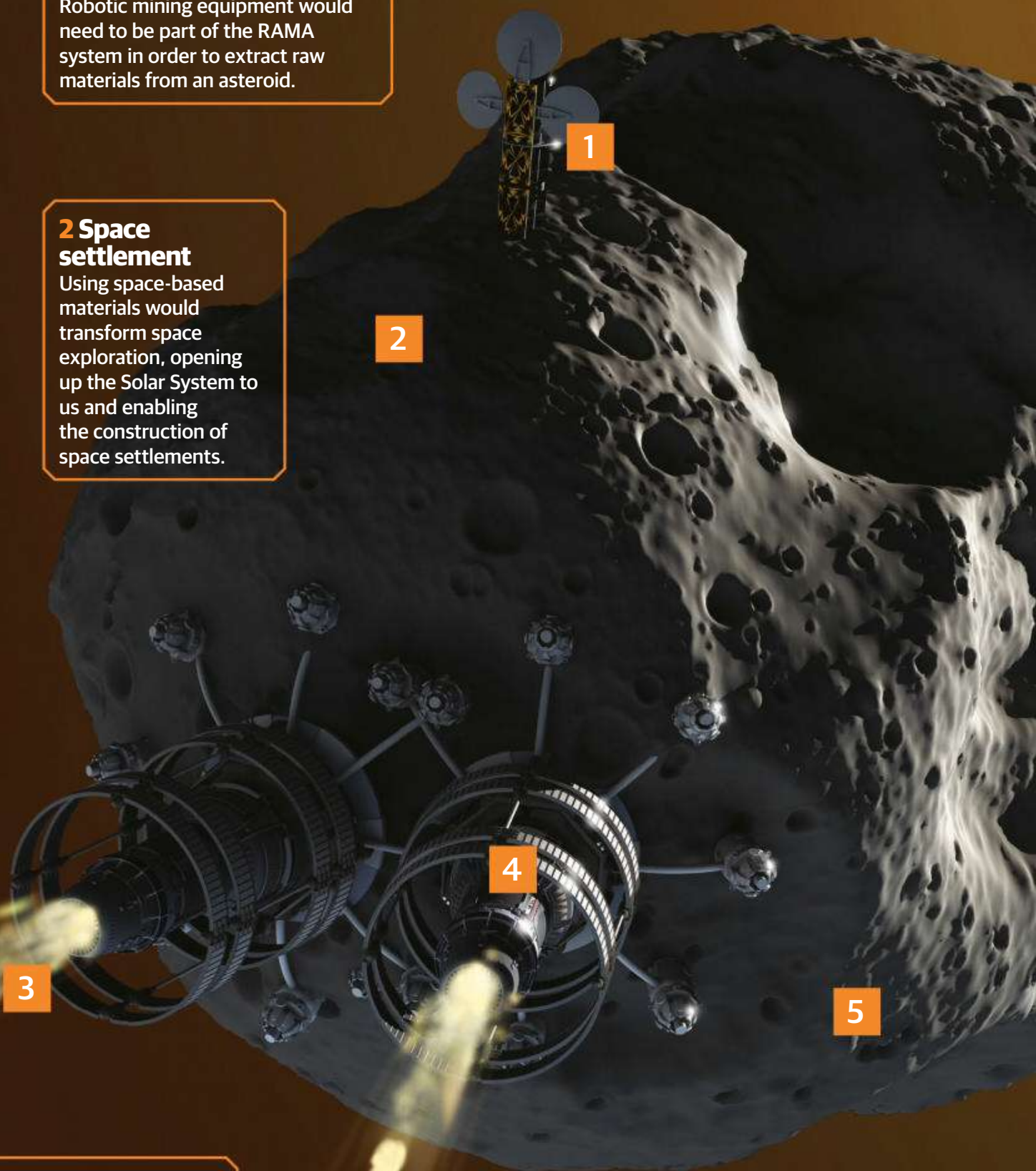
RAMA could deliver an asteroid, ready for processing, by using material from the asteroid for propulsion. This could be by expelling rocks or splitting water ice into hydrogen and oxygen.

4 Special delivery

Rather than converting the asteroid where it was found, RAMA would be able to transport it as a single bulk, ready for processing wherever its materials were needed.

5 Additive manufacturing

Additive manufacturing is efficient because it only takes the material needed for the finished product. Making objects in space also means that they don't need to cope with the stress of an expensive Earth launch.



7

7 Power supply

Little engineering detail has emerged as of yet, but it is likely that inner Solar System RAMAs would use solar power. From Mars outwards they would use nuclear power.

6 Asteroid

It is estimated that there are millions of asteroids in the Solar System, storing huge amounts of materials. All are potential candidates for a RAMA mission.

6

their luggage - but there are far more resources available up there.

The RAMA concept will likely consist of a whole range of technologies that could be deposited on an asteroid, where they could extract raw materials, process them into usable forms and pass them on. These materials could then be used for additive manufacturing to build things - possibly even bigger versions of the extraction and manufacturing systems. A small initial lander could build up an asteroid-scale installation out of the asteroid itself.

RAMA's other main system will be propulsion, which will use material from the asteroid as a reactive mass. In its most basic form this could mean firing rubble off the surface with an electromagnetic catapult. Better performance could be gained if the asteroid could provide water or hydrocarbons that could be used in a conventional rocket engine. Once a RAMA installation is in place on an asteroid it could be moved en-masse to wherever in the Solar System its resources were needed: a self-contained and propelled mine and factory all in one.

It only takes a small change in speed to gradually change the orbit of an asteroid, so as well as delivering resources to future space colonies, RAMA may also prove useful for Earth defence. Astronomers are making increasing efforts to track and record the orbits of potentially Earth-crossing asteroids. When a candidate is found, its orbit is analysed so that the uncertainty of its future path is reduced until we can be sure whether it will hit the Earth or not. Because of the consistency of orbits we should know this several years - even decades - in advance. A RAMA mission could then be sent to the offending asteroid to push it off course or collect it for its resources - saving the planet while also gaining materials.

Although NIAC projects are not expected to deliver immediate results, RAMA does build on technologies that are already maturing. Now it's just a question of scale. MIS could soon become one of humanity's most significant companies, making huge profits while enabling space settlement and protecting Earth from asteroid impacts in the process.

8

8 Hazardous asteroids

Asteroid impacts have happened before, and are likely to happen again unless we can deflect them. RAMA would be able to do this, gently using the asteroid's own resources to change its orbit.

THE HUNT FOR WHITE HOLES

The search for these eruptions in space-time has begun. Will they leave the pages of science fiction and enter reality?

Reported by Nicky Jenner



The cosmos is full of odd and extreme phenomena. Take everyone's favourite behemoth, the black hole, for example. These dark, mysterious objects hungrily devour anything and everything within their reach. However, there is a light side to accompany the dark - and the dark black hole has its light equivalent in the intriguing white hole.

In simple terms, white holes are time-reversed black holes. If you were somehow able to film a black hole in action and play the tape in reverse, you would see a white hole. Rather than furiously dragging in and trapping matter, as a glutinous black hole does, a white hole spews material out into space, allowing nothing to enter it.

White holes exist within the general theory of relativity. In mathematical terms, white and black holes are possible solutions that fit within the set of equations compiled by Einstein in the 1910s. These equations describe how mass interacts with and warps the fabric of space. Any object with mass has a gravitational effect on its surroundings; the greater the mass, the greater the gravitational effect.

The laws of general relativity, as with most of the laws of physics, can technically run both forwards and backwards. "If places where matter and energy

can enter but cannot leave fit the equations, like black holes, then places where matter and energy can leave but cannot enter, like white holes, must as well," explains Jeff Filippini of the University of Illinois at Urbana-Champaign. "There's nothing wrong with the idea mathematically - but that doesn't necessarily mean that white holes are real."

Unlike black holes, which we know exist, white holes are currently thought to be hypothetical objects that are unlikely to exist in reality. "We don't have any evidence for the existence of white holes in the visible universe," adds Steven Giddings of the University of California, Santa Barbara. "They're a theoretical prediction based on the time-reversal symmetry of the laws of nature. But time reversal also predicts that if we see a coffee cup fall and shatter on the ground, in principle there can be

"WHITE HOLES ARE A THEORETICAL PREDICTION
BASED ON TIME-REVERSAL SYMMETRY THAT
FORMS THE LAWS OF NATURE" **STEVEN GIDDINGS**

situations where all the pieces come together and assemble a coffee cup that flies up in the air, and we don't see things like that, which are in some respects similar to white holes."

While time-reversed processes - snooker balls coming back together to form an unbroken triangle, broken eggs reforming their shells, leaping coffee cups and white holes - violate no laws of physics, "we don't expect to see [them] happen naturally," explains Filippini.

Black holes form when massive stars use up their nuclear fuel, can no longer support themselves and collapse to create an infinitely dense point known as a 'singularity'. This point has such a strong gravitational field that it is surrounded by a region from which nothing can move fast enough to escape - not even light, rendering it invisible.

One of the major stumbling blocks for white holes is that, unlike with black holes, there is no known process that could create one. "Black holes are known to exist, and we know ways they can form, so they satisfy the equations and exist in the real universe," says Filippini. "But there is no process that I'm aware of that could actually make a white hole."

Some scientists have hypothesised that white holes could form via exotic processes. One theory involves quantum tunnelling, an odd phenomenon that allows matter to behave in bizarre ways on very tiny 'quantum' scales. This process could potentially enable black holes to transform into white holes.

Crudely put, if you fell into a valley without sufficient energy to climb out, you would be stuck there until a kindly passer-by offered to help. In quantum physics this is not true. Instead it is possible to 'tunnel' your way through an intervening hill into another valley. "Our thought was that maybe you could actually tunnel between different solutions of the equations of general relativity using a quantum theory of gravity," says Hal Haggard of Bard College, New York, one of the scientists behind the idea. "Quantum mechanically, you might be able to start with a black hole and have it tunnel into a white hole. However, these tunnelling processes are very rare, and nobody currently has a good grasp on how improbable they are. It could be that this is just so rare that it would never happen."

White holes might instead form as a result of a black hole forming in some other part of

Left: It is theorised that white holes are the opposite 'reaction' to a black hole, objects that also began as a theory until their detection

Below: Steven Giddings of the University of California, Santa Barbara, is an advocate for the existence of white holes

How white holes are made

1 Collapse of the core

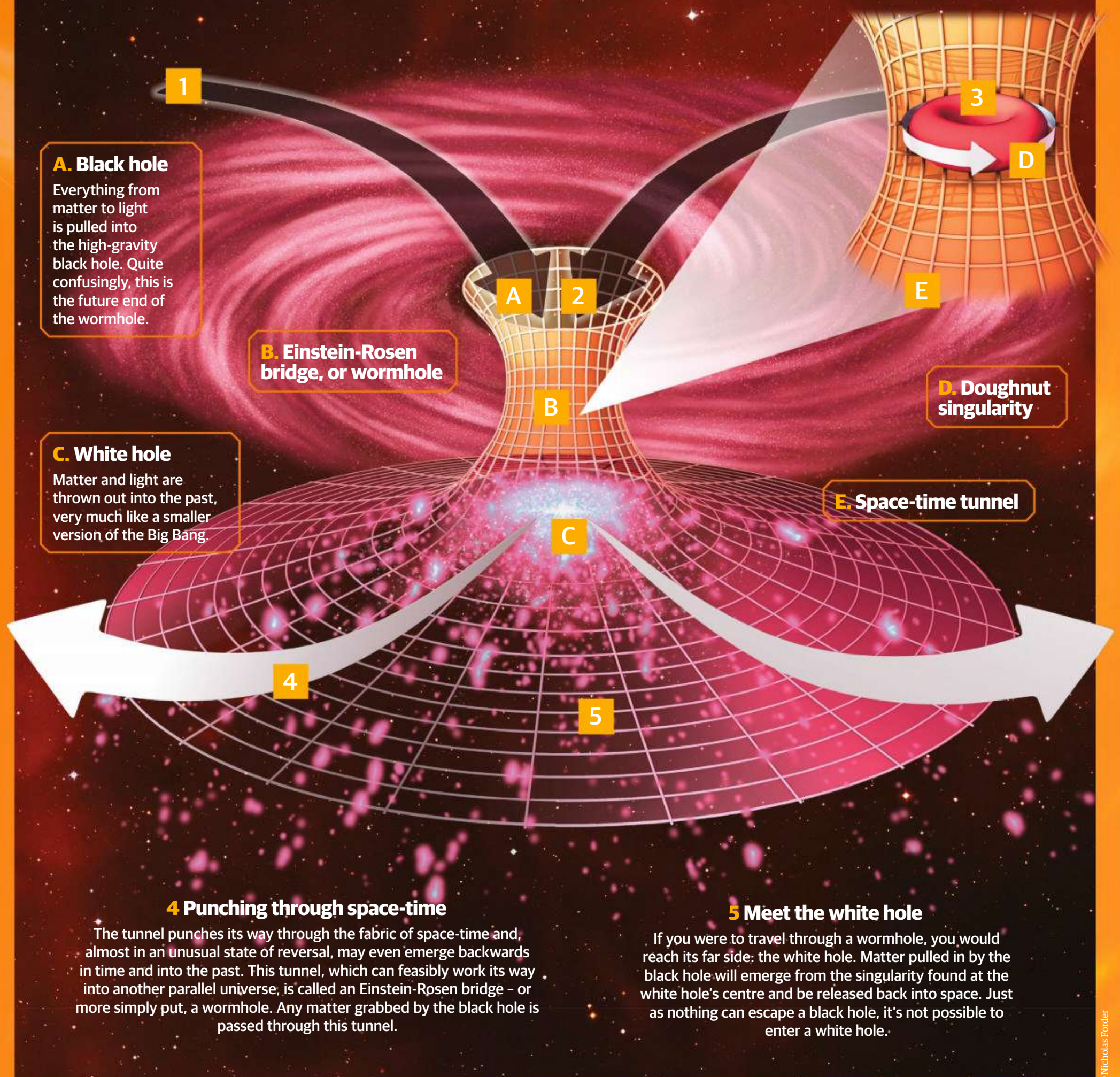
When a gigantic star – with a typical mass much more than 20 times the mass of the Sun – dies, sometimes a black hole is formed. When we refer to a star dying it means that it no longer has any nuclear fuel to burn, and this means that gravity is able to override the outward force. The core has no choice but to collapse in on itself, and the catastrophic explosion of a supernova results.

2 A cosmic plughole

Shrinking smaller and smaller, the core continues to pale in significance compared to its former stellar glory, collapsing further into an even smaller size. However, while it has shrunk to a speck, all of its mass is concentrated in a very small area. This is known as a singularity, which might be small, but is so very heavy that it has the ability to bend space-time.

3 The makings of a doughnut

A star's core can still be found to be spinning when it decides to collapse. Crumbling to the minuscule, yet hefty singularity, it begins to rotate faster and faster and spins so fast that what's left of the star's material spreads out and is moulded into a doughnut shape. Space-time is no longer focused on a single point; it's now finding itself being wrapped around this space ring, creating a tunnel.

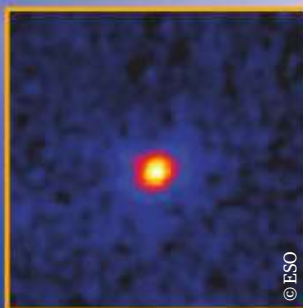


Have we already discovered one?

Detected in 2006, NASA's Swift gamma-ray mission could have uncovered a candidate for an 'inverse' black hole

A possible white hole?

Back in June 2006 the Swift satellite captured a burst of gamma rays that lasted for around 102 seconds in a galaxy some 1.6 billion light years away. Since no supernova was seen following the event, astronomers realised that they had come across a possible new object. In 2011 it was hypothesised that the burst was a white hole.

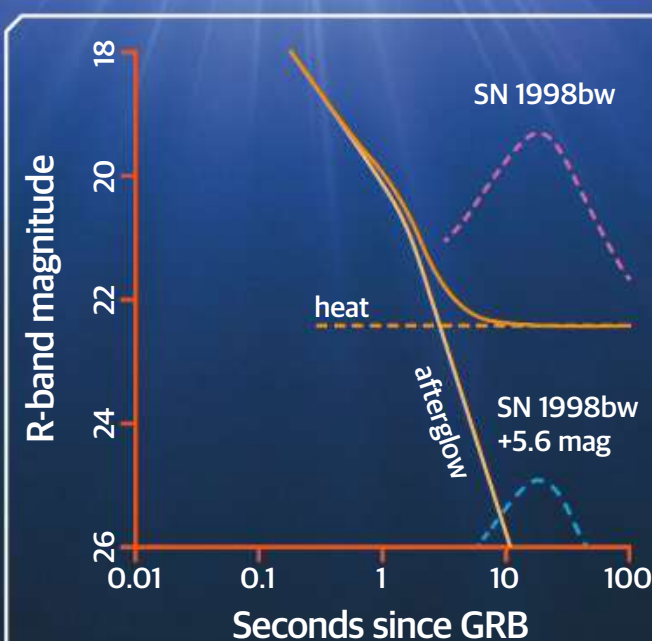


Mission profile: Neil Gehrels Swift Observatory

Launched:
20 November 2004
Operator: NASA
Launch vehicle:
Delta II 7320-10C
Orbit: Low-Earth

Super Swift telescope

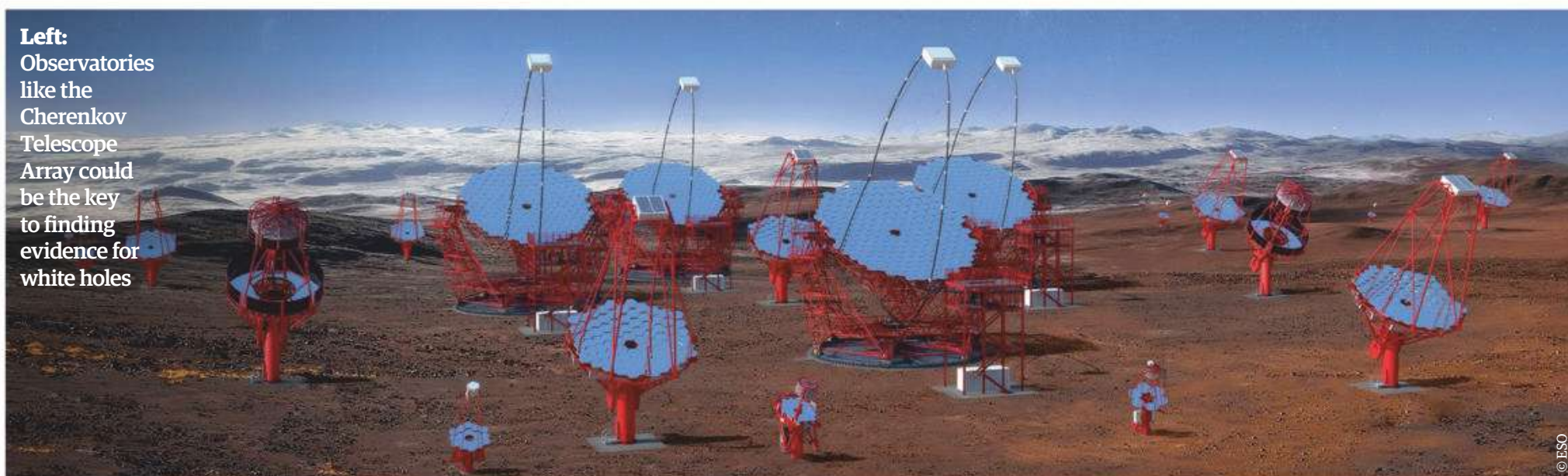
After being signalled by the Burst Alert Telescope (BAT) instrument on board, the Swift spacecraft slewed immediately to the burst. On detecting the mysterious object BAT made a light curve, which depicted an initial, bright, sharp peak followed by a long, but also bright and somewhat extended peak.



Possible origins

GRB 060614 has both the behaviour of a long and short burst, leaving astronomers to believe that its birth occurred in quite an unusual way. The burst sits in a galaxy with very few stars that could produce either an exploding star or a long burst.

Left:
Observatories like the Cherenkov Telescope Array could be the key to finding evidence for white holes



the universe - or another universe within the multiverse. In such a scenario, the white and black holes would be connected by a passage stretching through space and time, dubbed a wormhole. Matter would fall into the black hole, travel through the wormhole and pop out of the white hole somewhere else.

Although wormholes are a valid solution to Einstein's equations, "they're very tricky to describe in a way that doesn't sound like craziness," says Haggard. Wormholes are similar to white holes in that while they are mathematically possible, we know of no process that could form one. "There's more evidence against the possibility of wormholes than there is against white holes. To create one you'd need a very unusual, strange type of matter that we've never seen - so wormholes would be an extremely surprising phenomenon."

While we can't observe black holes directly, we can detect them by hunting for bursts of X-rays from superheated material and spotting stars and gas performing quirky dances around seemingly empty areas of space. From this scientists can infer the existence of a massive, invisible object lurking nearby that is disrupting its surroundings. This proved true for the centre of our own galaxy, which is believed to host a supermassive black hole called Sagittarius A*. White holes, however, would be eminently observable. They would spring to life, pour huge amounts of energy out into space and then disappear. In 2006 scientists observed something like this - a sudden burst of energy a couple of billion light years from Earth. This lasted for 102 seconds before stopping and disappearing.

Sudden, energetic explosions are not unusual in the universe. The most energetic events in the cosmos are flurries of high-energy particles known as gamma-ray bursts (GRBs); these are produced by extreme processes such as star collisions, stellar deaths known as supernovae and even star-black hole or black hole-black hole mergers. GRBs come in two classes dependent on their duration and other properties, and each is thought to form differently. Scientists assumed the 2006 blast to be an example of a GRB, and named it accordingly as GRB 060614. However, its properties were peculiar and placed it in neither known class. More confusing was the fact that there appeared to be no suitable progenitor in the patch of sky that hosted GRB 060614; it seemed as if the explosion had come from nowhere.

In 2011 a duo of scientists suggested that the event may have been the first observed occurrence of a white hole. "Recent observations suggest that there is a third class of GRBs, the prototype of [which] is GRB 060614," wrote Alon Retter, one of the scientists behind the theory. "[These] GRBs are

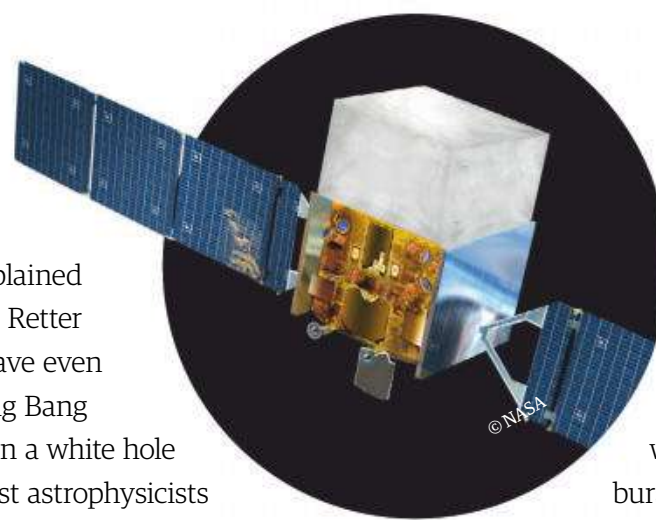
long, close, lack any supernova emission and are naturally explained by white hole blasts." Retter and his colleagues have even suggested that the Big Bang itself might have been a white hole springing to life. "Most astrophysicists believe that there are no white holes, but we and a few other researchers are convinced that they must exist," says Retter. "The Big Bang, the singularity point at the beginning of the universe, is clearly a gigantic white hole that ejected all or most of the mass in the universe."

A Big Bang-like explosion is indeed superficially similar to what we might expect to observe if we saw a white hole, and aspects of GRB 060614 also ring true, but both ideas are highly speculative. "Was the Big Bang a white hole? I wouldn't go there," says Haggard. "The bounce of a Big Crunch - collapse of the universe - to a Big Bang - expansion of the universe - is analogous to the bounce of a

black hole to a white hole, but I'm not sure that there's a correspondence in the physics of the two situations."

Another phenomenon that could possibly be linked to white holes is that of fast radio bursts (FRBs). These are incredibly short-lived, intense bursts of energy of unknown origin from outside our galaxy. However, there are indications that these FRBs may pulse periodically, which would make them less likely to be connected to white holes.

Despite their status as hypothetical objects, there are observatories that would be able to detect them. The Laser Interferometer Gravitational-Wave Observatory (LIGO) is the largest gravitational-wave hunter in existence. Gravitational waves are linked to the most extreme and high-energy phenomena in the universe, like black holes, neutron stars and supernovae. LIGO has characterised unusual types of black hole, discovered collisions between them



"THE BIG BANG, THE SINGULARITY POINT AT THE BEGINNING OF THE UNIVERSE, IS CLEARLY A GIGANTIC WHITE HOLE" ALON RETTER

Above: By using satellites we hope to track the existence of white holes

Right: Gamma-ray bursts could exhibit the same behaviour as white holes

Below: Haggard argues that white holes should be more than just a theory



White holes

and more. The observatory could also spot white holes, although there appear to be no current plans to search for them directly.

Other potential white hole observatories include the Cherenkov Telescope Array (CTA), which is currently under construction and will hunt for high-energy gamma-ray sources, and the Fermi Gamma-ray Space Telescope (FGST), a space telescope currently in orbit around Earth that aims to characterise GRBs. "We must look for the structure of magnetic fields near the centres of galaxies," says Russian theoretical astrophysicist Igor Novikov, who points out that general relativity allows for the existence of white holes. "If the structures of the magnetic fields appear to be magnetic monopoles [magnetic phenomena that have only one pole, which have so far proven elusive] that are macroscopic in size then this is a wormhole." It turns out that wormholes - specifically their white holes - will emit their own radiation, in contrast to black holes that spew intensive radiation from the swirling gas that surrounds them.

While white hole research remains highly speculative and the concept remains hypothetical, the same was once true for black hole research, Haggard points out. "When people first discovered black hole solutions in general relativity they said, 'this could never really happen; it's such a strange idea'," he says. "That was the textbook explanation of them for many years: 'this is just a weird solution'. We now know that's wrong! Black holes turned out to be ubiquitous, and there's a lot of evidence for them now. My stance is to be open-minded about white holes; mathematics doesn't say they can't exist, so we should look into them.

"We'd love for astrophysicists to go out and look for experimental signatures and either constrain them more tightly so that it's less likely that they're there, or find evidence, which would very much increase their odds of existing in the universe."



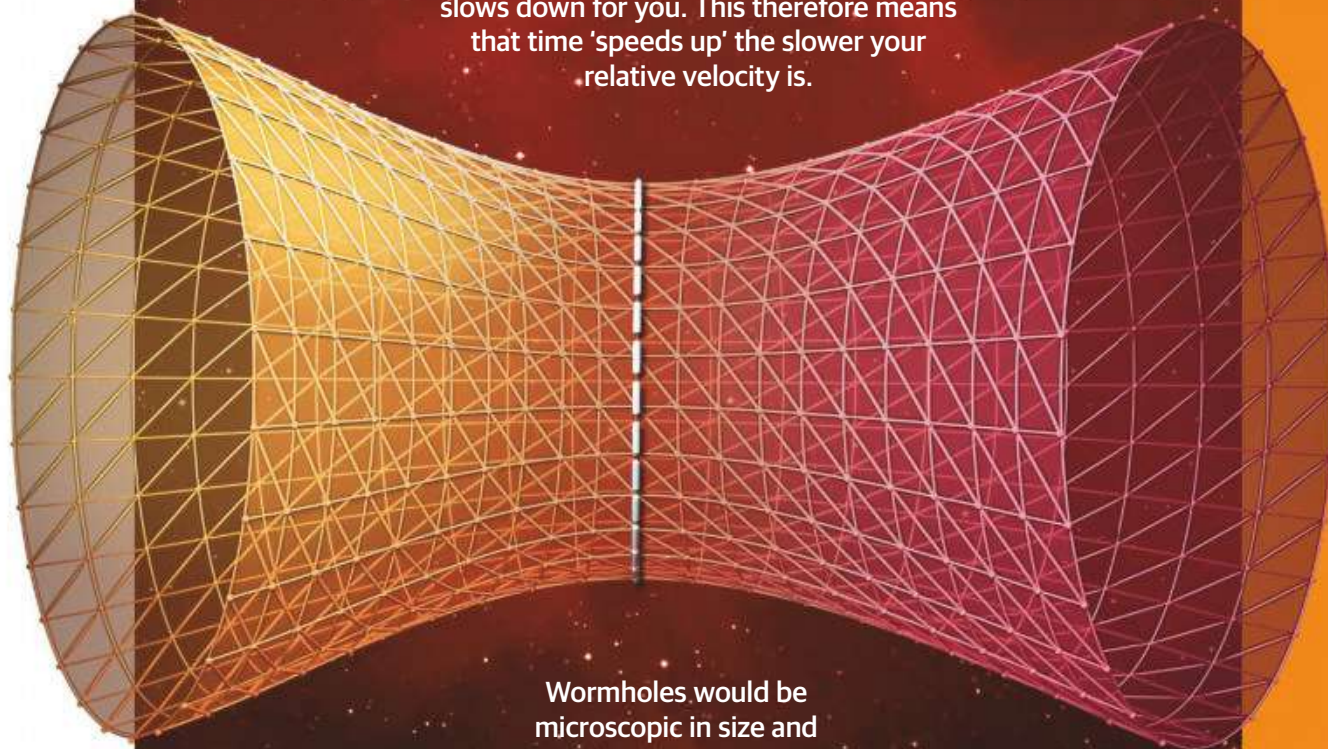
Left:
The 43 Meter
(140 Foot)
Telescope at
the National
Radio
Astronomy
Observatory
(NRAO)

Linking white holes and black holes: the wormhole

Wormholes are based on Albert Einstein's theory of general relativity, a theory which suggests that objects with a great gravitational field create a depression in the fabric of space-time. It is this theory that is able to predict phenomena such as black holes. If the mass of a collapsed star is great enough, it can warp space-time to such an extent that matter is sucked into the hole created by the object's gravitational mass. Back in 1916 physicist Karl Schwarzschild offered that where matter is sucked in, on the opposite end matter is spat back out again, which could possibly be in the form of a white hole. According to physicist Kip Thorne the tunnel-like shortcut that connects them - known as an Einstein-Rosen bridge after Albert Einstein and Nathan Rosen - could serve as a means of time travel with help from time dilation.

If you move one of the 'mouths' of the wormhole to a great speed while the other remains still, the progression of time would be different at the opposing ends. We aren't able to travel back in time, but we can move through to the far future or return to the near present with the help of a wormhole.

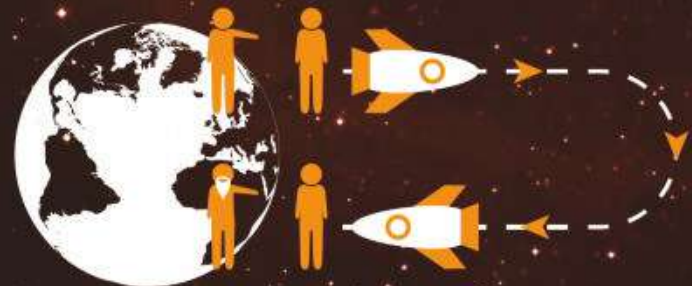
The greater your speed, the more time slows down for you. This therefore means that time 'speeds up' the slower your relative velocity is.



Wormholes would be microscopic in size and potentially undetectable at just 10^{-33} centimetres.

Time dilation

This is the theory that the speed of time ticking by is relative to how fast you're moving and how close you are to a large gravitational force - such as a black hole. The greater your velocity, the slower time passes.



Time-travel paradoxes



Grandfather paradox

The grandfather paradox implies that if you were to go back in time to kill your grandfather, you would not be able to exist to kill him since he wouldn't be able to reproduce.

Predestination paradox

If a defining event happened to you now, this paradox suggests that there is a possibility that it's caused by a future you travelling back in time in order to make sure it happens.

3 FREE DIGITAL BOOKS FOR EVERY READER!



BOOK OF MARS

The history of Mars is intrinsically bound up with that of Earth - some scientists even think that the original building blocks of life came from there. The European Space Agency's Mars Express probe, undeterred by the failure of its Beagle 2 lander back in 2003, recently beamed back some of the clearest images yet of a crater filled with water ice in the northern lowlands of what was once thought to be an arid world. Despite a chequered history of failed spacecraft and the so-called 'Mars Curse', the Red Planet is finally giving up some of its secrets. In this book it's revealed what scientists know so far about the planet and the theories that may help us to understand it further, exploring how one day we could make it into another human home.

ASTRONOMY FOR BEGINNERS

Armed with nothing more than your eyes a basic grasp of where to look in the night sky, you can embark on one of the most rewarding hobbies in the world. Planets, stars, constellations, nebulae, meteor showers and many other celestial objects can be spotted using only the naked eye. And for those with telescopes, the universe is a vast gallery of a trillion cosmic wonders. Easy-to-follow guides will furnish you with all the essentials, taking you on a journey from stargazing hobbyist to becoming a fully equipped astronomy enthusiast. With practical guidance, seasonal sky charts and pointers on how to spot some of the sky's most accessible sights, this new edition of **Astronomy for Beginners** will be your companion as you unravel the beauty of the sky.

BOOK OF THE MOON

We've been looking up at the Moon for millennia, but it was always just out of reach. Then everything changed. On 20 July 1969, humankind achieved what had previously been thought impossible: two astronauts landed on the surface of the Moon for the very first time. More Moon landings followed in an era since dubbed the golden age of space exploration, but our curiosity is far from sated. In **Book of the Moon**, find out what really happened when Neil Armstrong and Buzz Aldrin stepped outside their Lunar Module and uncover what is being done to preserve that moment in history before taking a tour of the craters and maria. Learn how to take the perfect photograph of our lunar neighbour, and discover what's really on the Moon's far side.

DOWNLOAD YOURS NOW AT: [SURVEYMONKEY.CO.UK/R/3FGFLNZ](https://www.surveymonkey.co.uk/r/3FGFLNZ)

Did you know?

There are three main classifications of galaxies: elliptical, spiral and irregular. Spiral galaxies account for 77 per cent of those observed.

ASTROPHYSICS

How can a galaxy appear to have a massive hole in the middle?

The massive hole in the middle is caused by a collision with another galaxy. However, not all galactic collisions result in gigantic holes. Only a head-on collision, similar to a 'bullseye shot', can produce a hole surrounded by a ring, or sometimes multiple rings. The hole is formed as the galactic 'heart' gets knocked off, and stars at the inner parts of the galaxy oscillate outwards in response to the gravitational disturbance. The rings are density waves that spread out from a single point.

In addition to a bullseye collision, two additional conditions must be met. Firstly it needs a thin galactic disc to serve as an 'aiming board' and a smaller galaxy to be the bullet, and secondly it needs a cheering cosmic environment where the 'galactic Olympic shooting games' can be held without any disruptions. In the current

universe such conditions are easily met, and all we need is a bullseye champion.

In the young universe there were more 'Olympic games', but the two conditions were compromised. There were not many aiming boards and the cosmic environment was very chaotic, with constant gas accretion and many satellite galaxies dancing around. A galaxy with a gigantic hole seems to be a rare phenomenon throughout the history of the universe: only one out of 10,000 galaxies would hold the title of a collisional ring galaxy.

Dr Tiantian Yuan is an ASTRO 3D fellow at the Centre for Astrophysics and Supercomputing at Swinburne University of Technology, Melbourne, Australia



Above:
An artist's impression of a super-rare galaxy, described as a 'cosmic ring of fire'

SPACE EXPLORATION

How does the human body's immune system change in space?

Our immune system is vulnerable to the rigours of space. During missions, astronauts undergo the effects of the exposure to harsh environmental conditions such as microgravity, heavy radiation, variable magnetic fields, altered circadian rhythms, lack of movement and isolation as well as altered immune functions and increased vulnerability to infections during and after flights.

In general the examination of the status of the astronauts' immune systems reveals that there is a conversion from primed immune activity after acute gravitational stress to a progressive decay of the functionality of the immune system after several days of spaceflight - the longer the time spent out of Earth, the higher the effects on the immune system. These alterations progressively return to normal levels up to one year after return.

This represents a reality that should be more comprehensively analysed to ensure the feasibility of eventual long-range expeditions to the Moon, asteroids or other planets. To date only 24 astronauts have been beyond low-Earth orbit, thus the real consequences of long space travelling in human immunity remain largely unknown. Reducing the uncertainties in the adaptation of the immune system to long space flights is necessary before launching manned missions to interplanetary space.



Jorge Domínguez Andrés is a research associate at the Radboud University Nijmegen Medical Center, The Netherlands

Right: Almost half of the Apollo crew members suffered from an infection of sorts during, or up to seven days after their missions

Below: The night sky today is stunning, but imagine what it was like 10 billion years ago



"Our immune system is vulnerable to the rigours of space"

Jorge Domínguez Andrés



COSMOLOGY

Did the Milky Way look different 10 billion years ago?

The universe has not always been as we observe it nowadays. In the past the cosmos was more densely packed with galaxies than today, interactions and mergers were more common and star formation proceeded at a violent rate. Our galaxy was not an exception.

Indeed, we now know that the Milky Way was in the process of merging with another system named Gaia-Enceladus around 10 billion years ago, one of the more important mergers our galaxy has experienced in its entire life. As a consequence, hypothetical inhabitants of our galaxy that were observing it 10 billion years ago would enjoy quite a different and amazing view.

The Milky Way was in a puffy and somehow distorted configuration, in contrast with the ordered disc that we can observe from dark skies. New stars were constantly born from vast reservoirs of gas and dust, as well as supernovae explosions abound. All in all, if spectacular is the observation of a starry night today, the show was assured 10 billion years ago: an ongoing merger, gas, dust, breathtaking nebulae and supernovae explosions every now and then are some of the events that could be observed in a single night.



Dr Tomás Ruiz-Lara is an astrophysicist at the Instituto de Astrofísica de Canarias (IAC), Santa Cruz de Tenerife, Spain

COSMOLOGY

What did the universe's first planets look like?

We think that the first generation of stars didn't form planets. These stars were very unstable and likely developed in a short time very strong winds, violent pulsations and eventually exploded. All of these processes contributed to releasing new chemical elements that formed in the interior of these stars in the nearby gas, changing forever the chemical composition of the universe.

The information we've collected so far indicates that gaseous giant planets are normally found orbiting metal-rich stars, while small rocky planets can be found both around metal-rich and very metal-poor objects. The current explanation for this is that larger gaseous planets would need larger cores to form, and in the discs of metal-poor stars there may not be enough heavy elements.

For these reasons we believe the first planets in the universe were likely small rocky systems. This is also supported by the properties of the oldest planetary systems discovered so far. These are compact groups of small rocky planets orbiting around stars that are about 13 billion years old.

Dr Elena Sabbi is NIRSpec branch manager at the Space Telescope Science Institute, Baltimore, Maryland



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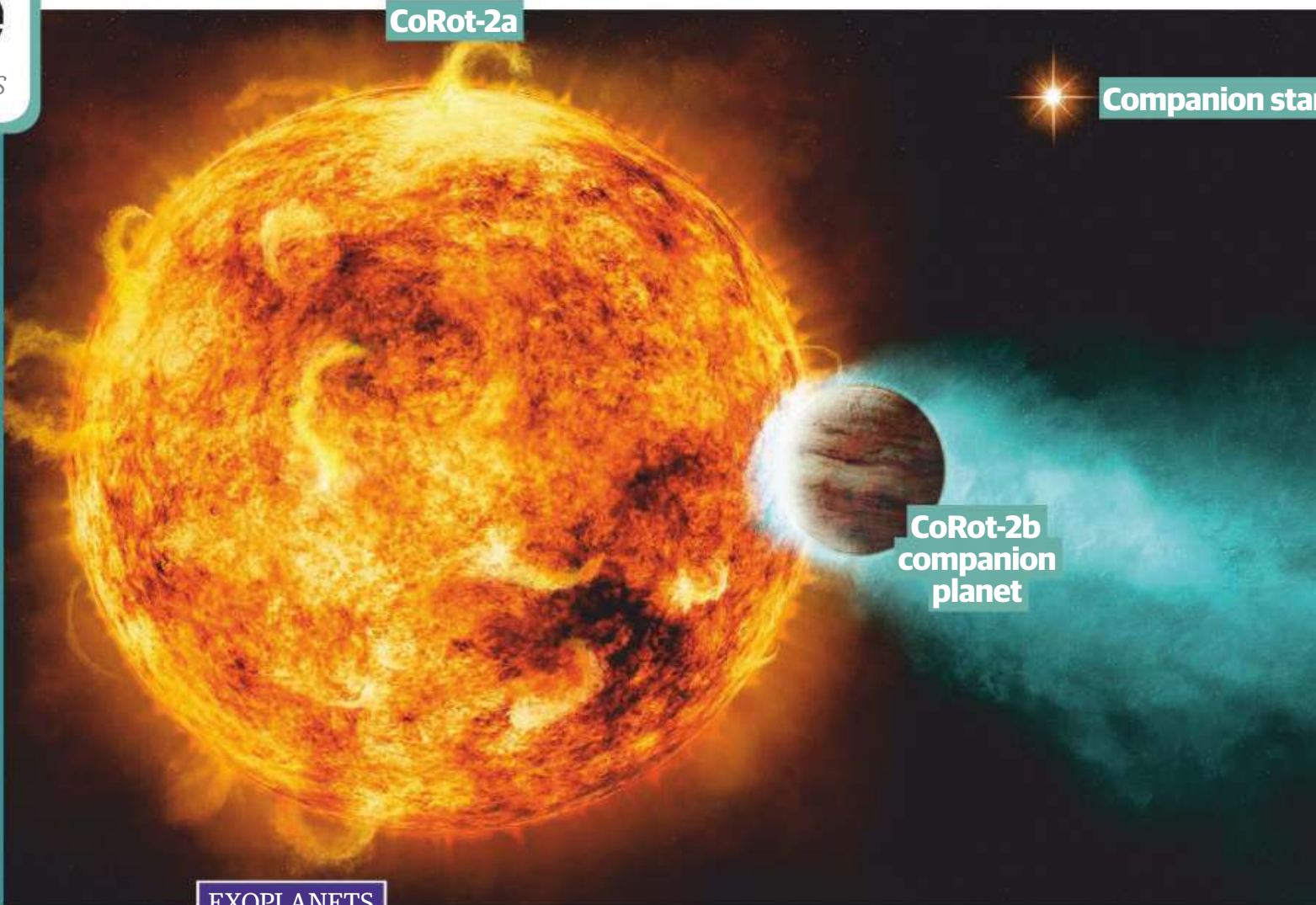
Above: If a planet gets close enough to its host star, layers can be stripped off by intense radiation

Right: Hubble has been damaged by space debris, which is then fixed at a cost

CoRot-2a

Companion star

CoRot-2b companion planet



© NASA

EXOPLANETS

Could hot Jupiters have dust trails similar to comets seen in the Solar System?

There are a couple of hot Jupiters and warm Neptunes that have been observed or inferred to possess 'gas' tails. These two bodies are a particular genre of exoplanet that are similar in size, and inferred composition, to Jupiter and Neptune, the main difference being they are orbiting much closer to their host star, and consequently fall victim to harsher temperatures.

These gas tails are caused by the intense irradiation experienced by these planets launching an escaping wind of hydrogen and helium from their upper atmospheres. Once aloft these gases are shaped by stellar winds into a tail. Hydrogen and helium are able to form a tail because they are light molecules. Dust particles, on the other hand, are much heavier, and thus should not be able to escape a hot Jupiter's atmosphere to form a tail.

That said, there have been observations of much smaller exoplanets - perhaps Moon- or Mercury-sized - that possess large dusty tails of small rock particles. These have been hypothesised to arise from an escaping wind of rock vapour from these planets' surfaces that then condense into dust and are propelled into a tail by stellar winds.



Dr Peter Gao is a postdoctoral fellow at the University of California, Berkeley

SPACE EXPLORATION

How much would the damage brought about by colliding space debris cost?

A catastrophic collision would cost an operator the lost revenues from the destroyed satellite, plus replacement costs if they replace it. But these are just private costs; there's also a cost that's external to the immediately affected operator. The fragments from the collision could cause future collisions, which would impose similar costs on other operators. Those collisions might generate more fragments, which impose more costs.

My colleagues and I have estimated the external cost using sector-level aggregate data on satellite costs and revenues, estimates of collision risks in low-Earth orbit (LEO) and statistical models of

debris production. We estimate the cost as of 2020 in the ballpark of £12,000 (\$15,000) per satellite in LEO in a single year. With around 1,500 satellites in LEO, that's about £17.8 million (\$22.5 million) in a single year in total external costs. These fragments make the orbital environment costlier to use. While some operators might be able to modify their mission or business plans to avoid or incorporate these costs, some potential operators would be deterred from launching satellites.



Dr Akhil Rao is an assistant professor of economics at Middlebury College



© ESA

ASTROPHYSICS

What is a 'fast blue optical transient'?

If you observe a patch of sky repeatedly, you will see objects that suddenly appear, brighten and then disappear. We call these objects 'transients'. For example, stellar explosions, or supernovae, are one type of transient. In recent years, as astronomical surveys have been observing the sky more frequently, astronomers have identified a new class of transient that appears and disappears in just a few days. As these transients are fast and blue at optical wavelengths, we call them fast blue optical transients (FBOTs).

It is not yet clear what FBOTs are. They are too bright and fast to be 'normal' supernovae. One leading model is that they are explosions of stars that have shed a lot of material into space before they exploded. The FBOT is then the brightening and cooling of this material as the supernova blast wave runs through it - in other words, this material changes the supernova's properties and how it looks to us. However, we now know of at least three FBOTs - AT 2018cow, CSS161010

and the Koala - where the FBOT is powered by a black hole or neutron star. This would form in the core of the stellar explosion and then launch a powerful jet.

In this case the FBOT could be the light from this process as seen through the surrounding material. In the upcoming years as we observe more FBOTs across the electromagnetic spectrum, we will be able to conclusively distinguish between these and other models.

Dr Deanne Coppejans is a postdoctoral associate at the Center for Interdisciplinary



Exploration and Research in Astrophysics (CIERA), Northwestern University, Illinois

Below: The Crab Nebula (M1) is a great visual example of a star that has shed its layers

Did you know?

A supernova occurs somewhere in the universe every second. However, the Milky Way only has an average of two per century.

DAYTIME ASTRONOMY

Forget staying up late – All About Space reveals how you can get stuck into observing without waiting until the small hours

Written by Stuart Atkinson

W

hen most people think of astronomy they picture someone standing outside on a sparkling clear night, gazing up at the wonders of the universe, perhaps using a telescope or pair of binoculars, or just sweeping the night sky with their eyes, taking in the view of stars, planets, the Milky Way and other natural nocturnal wonders. Indeed, a Google image search for 'astronomy' will bring up hundreds – even thousands – of pictures of people standing on their own, or in a small group, peering into telescopes beneath a star-dusted sky long after the rest of the world has gone to bed.

As the old joke goes, astronomy is the perfect hobby for three types of people: insomniacs, burglars and vampires. But astronomy doesn't have to be such an anti-social pastime, and it doesn't have to be done between sunset and sunrise either.

It's possible to do astronomy in the daytime; in fact, it's a good idea for every stargazer and sky-watcher to know what there is to see in the daytime sky because those aforementioned sparkling clear nights are few and far between, and when they eventually arrive our views of celestial phenomena and events are often spoiled because of light pollution. So, what can you see in the daytime sky?

© Getty

TARGET #1

The Sun

While it's our nearest star, the Sun can be a challenging target without the right equipment

The most obvious thing to look for and study in the daytime sky is the Sun. One of the very first things that someone 'getting into' astronomy learns - and is amazed by - is that the bright white ball they have seen shining brightly in the sky above them all their lives is in fact a star - the closest star to Earth. The night sky is full of distant suns, each tiny, twinkling dot a star like our own. Well, not exactly like it; some stars are bigger than our Sun, while some are smaller. Some are hotter, and some are cooler. However, like all the stars in the night sky, our Sun is an enormous, hot ball of gas that keeps burning through

the process of nuclear fusion, providing us here on Earth with the light, heat and energy we need to survive. And because the Sun is a star, when you look at it you are definitely doing astronomy.

The good news for anyone wanting to observe the Sun is that it is much closer than almost every other astronomical object. Just 150 million kilometres (93 million miles) away, it is nearer to Earth than everything except the Moon and a couple of Earth's sister planets. Its close proximity means we are able to see and study it in great detail from here on Earth - but only if we use the right equipment. The Sun is incredibly bright,



Left: Solar projection is a great way to view sunspots and solar eclipses

TARGET #2

The planets

It is sometimes possible to see planets in the daytime sky, but only if you have very good eyesight, you know exactly where to look and at what time of day, if they are well away from the Sun and the sky is very clear with no clouds.

The planet most easily seen in the day is Venus, as it's the brightest. When it's at its farthest point from the Sun, keen-eyed people can sometimes pick it out from the blue sky as a spark of silvery light. Others need binoculars to find it. Be careful, though, as you should never look for any planet without hiding the Sun behind a building or hill so you don't accidentally look at it while planet hunting.



© ESO

“THE GOOD NEWS FOR ANYONE WANTING TO OBSERVE THE SUN IS THAT IT IS CLOSER THAN ALMOST EVERY OTHER ASTRONOMICAL OBJECT”

View sunspots the easy way

You can observe sunspots – magnetic storms on the surface of the Sun – safely by projecting an image of the Sun onto a paper or card screen using just a pair of binoculars. If you have a clear view of the Sun for several days in a row you can watch how the sunspots change their shape and size as they are carried across the Sun's face by its rotation.

1 Select a piece of white paper or card to use as a screen – make sure it is very clean, without any patterns or blemishes.

2 Cover up one of the lenses of the binoculars so only one image will be projected.

3 Position your screen behind the binoculars.

4 Align your binoculars with the Sun by holding them towards it and moving them around until a bright circle appears on the screen behind them. Do not look through the binoculars.

5 Sharpen the Sun's image by turning the focusing wheel on the binoculars.

6 Adjust the size of the image of the Sun by moving the binoculars and screen apart.

7 If there is any sunspot activity on the Sun you will see the sunspots as small, dark markings on the bright solar disc.

8 If you can view the sunspots for several days in a row you will be able to see them change shape and size as they are carried across the Sun's face by the rotation of the Sun.

9 Even if there are no sunspots visible on the Sun when you look, check for any large sunspot groups just coming into view on the edge of the Sun.



Above: Special glasses are used for solar viewing, in particular solar eclipses

and it is so bright because it is so hot: on its surface the temperature is a stunning 6,000 degrees Celsius (10,832 degrees Fahrenheit), and its core is even hotter. That means anyone wanting to observe the Sun has to take care and use special equipment and techniques, or else they risk serious eye injury or even permanent blindness. With the right gear, and a healthy amount of caution and common sense, our closest star can be a fascinating object to study before the more distant stars come out.

One simple and safe way of observing the Sun is to simply look at how its shape and colour changes through the day depending on how much cloud it is shining through, how high it is in the sky and so on. When the Sun is high in the sky, or overhead, it is an eye-wateringly bright object. When the Sun is about to set, or has just risen and is low in the sky, it can appear bigger, bloated and more orange in colour than when overhead. This is because we are looking at it through more of the atmosphere, so its light is refracted and distorted, making it appear squashed and bloodshot – and a lot less bright, too.

But even when it is low and dim you still have to be very careful not to look directly at it for more than a moment, or you will risk damage to your eyes.

Because it has always just looked like a bright, blank white disc in the sky, newcomers to astronomy are often amazed to learn that there are fascinating features to be seen on the face of the Sun, and they want to see them. However, to see dramatic solar features such as sunspots, prominences and flares you have to find a way to magnify the Sun's disc, which is surprisingly small. It's easy to magnify the Moon or objects in the night sky – all you have to do is look at them through a pair of binoculars or a telescope. But if you use those instruments on the Sun you will concentrate its light and heat into intense beams that will cook your eyes like fried eggs. However, with the right equipment and techniques it is possible to enjoy stunning views of the Sun in a perfectly safe way.

The easiest way is to use solar projection. This involves projecting an image of the Sun onto a

TARGET #3

Iridium flares

Many sky-watchers and stargazers enjoy spotting the bright flares from the solar panels of satellites. The brightest can outshine everything in the sky apart from the Sun and the Moon, appearing as a dazzlingly bright point of light that fades after a few seconds. The brightest of these can be seen in the daytime if you know exactly where and when to look. Apps and websites will tell you when and where you have a chance of seeing one, but you'll have to be quick.



Source: Wikipedia Commons © Christos Doudoulakis

suitable surface and studying that image instead of looking directly at the Sun itself. To project a solar image you will need either a pair of binoculars or a small telescope, and a piece of white paper or card to place behind them to use as a screen. By carefully positioning the binoculars or telescope between the Sun and the screen at just the right angle so the Sun's rays go straight through their lenses and form an image on the screen, you will produce an image of the Sun large enough to show any dark sunspots on its face at that time. Sometimes the Sun is completely blank, so don't worry if you can't see anything the first time you look! You can change the size and sharpness of the image by moving the screen closer or further away, and by focusing it in the usual way.

Using projection you can watch sunspots as they appear from around the limb, then follow them as they track across the disc, changing shape and size. The advantages of using solar projection to observe the Sun are many. It is very simple, very quick and cheap, too. It also means several people can see the Sun at the same time. However, it is absolutely vital you don't look through the projecting equipment or let your skin or anything else wander into the path of the light. Remember how you used to burn paper with the Sun and a magnifying glass when you were younger? Solar projection works on the same principle, so be very careful.

It might seem pretty obvious that if you want a more detailed view of the Sun you will need to magnify it more – but how, if looking directly at the

Sun through a telescope is dangerous? The solution is to fit your telescope with a special filter which reduces its brightness to a fraction of a percent of its usual brightness, then you can use your standard telescope and eyepieces to zoom in on its surface features just as you would zoom in on lunar craters, star clusters or the planets.

The most common and popular type of solar filter is the Mylar filter. Mylar is a very special material that looks deceptively like silver kitchen foil or the material helium balloons are made of, but is in fact a very dense, very lightweight specialised material astronomers have been using for decades now. You can either buy a ready-made Mylar filter produced specifically for your telescope make, model and size, or you can send off for a small sheet of the material and then make your own filter using a hoop of strong cardboard that pushes over the front of your telescope. There are lots of solar filter-making guides available online, or from your local astronomical society.

Using a Mylar solar filter means you can magnify the Sun dozens or even hundreds of times, allowing you to see some very fine detail within and around sunspots and see how they change shape over time, with areas appearing and disappearing, different small groups of sunspots joining up to make larger groups and other solar phenomena. You will also be able to see the 'granulation' of the Sun's surface, which many people think looks like the outer peel of an orange seen through a magnifying glass.

Solar filters are safe as long as they are made of the correct material – so be careful not to buy cheap filters online which may be made from material that will not protect your eyes – fitted properly and are not suffering from general wear and tear – any holes or scratches, however small, could let sunlight into your eyes

Below: A Mylar filter can turn any telescope into a solar instrument



“USING PROJECTION YOU CAN WATCH SUNSPOTS AS THEY APPEAR FROM AROUND THE LIMB, THEN FOLLOW THEM”

Watch the Sun live

If you don't have the special filters or expensive telescopes amateur astronomers use to observe and study the Sun, don't worry – you can still keep an eye on it, even if the sky is cloudy! There are now free apps for smartphones and tablets that let you explore the Sun and monitor its activity. You will find them with a quick search of your app store. If you don't have a smartphone or device you can do the same thing via the website of NASA's Solar Dynamics Orbiter, a Sun-watching observatory.

1 Go to the SDO website using your web browser: sdo.gsfc.nasa.gov.

2 Navigate to the menu bar at the top of the page.

3 Select 'Data' from the menu, and a drop-down list will appear.

4 Select 'The Sun Now' from this drop-down menu.

5 When 'The Sun Now' is highlighted in blue, scroll down the page to view images of the Sun taken at different wavelengths.

6 First select the view of the Sun in Hydrogen-alpha by scrolling down to the image labelled 'AIA 304'. This will allow you to see any prominences on the edge of the Sun. The Sun's disc will appear a deep-red or deep-orange colour in this wavelength.

7 If you see any crimson loops, arches or feathery towers suspended above the limb of the Sun, these are prominences. Zoom in on them to see more detail.

8 Look out for any bright spots or squiggles on the Sun's face. These might be very powerful solar flares.

9 To see the Sun in 'white light', scroll down to the views labelled 'HMI Intensitygram'. There are three different ones. All show the view you would have of the Sun if you were projecting its image. These images of the Sun appear gold, yellow and white. The colours don't really matter. These views will allow you to see any sunspot activity on the Sun at that time. They will look like small, dark spots.

10 Zoom in on any sunspots visible so you can see their structure more clearly. Look out for the very dark centre 'umbra' region and the lighter, streaked 'penumbra' that surrounds it.

11 You can also use the website to view videos showing recent solar activity. Click on a link that says 'MPEG' and a file will be downloaded to your computer. It will let you watch sunspots coming into view over the limb of the Sun several days earlier and show how they have changed shape and size since then. They will also reveal prominences forming before these solar flares fall away again.

“SHOULD YOU SEE A BRIEF FLASH OF PINK OR WHITE YOU’LL HAVE BEEN LUCKY ENOUGH TO WITNESS A RARE SOLAR FLARE”

TARGET #4

Solar and lunar Space Station transits

Spotting the International Space Station (ISS) is now a very popular part of amateur astronomy – and many of you reading this would be thrilled at the sight of the ISS sailing silently across the sky, shining like a bright star. On very rare occasions the ISS’ path across the sky takes it between us and the Moon or the Sun, and for a couple of seconds it can be seen silhouetted against it. To catch one of these transits you have to be in exactly the right place at exactly the right time, as predicted by phone apps or websites.



Source: Wikipedia Commons © Public Domain

Naked-eye solar effects

Sun dogs

Sun dogs, known more scientifically as 'parhelia', look like miniature rainbows on either side of the Sun when it is low in the sky, either just before it sets or just after it has risen. They are caused by the Sun's light being refracted and reflected by ice crystals in the upper atmosphere.



Solar halo

A solar halo is a glowing halo around the Sun. All solar halos have a radius of 22 degrees. Solar halos are usually seen when the Sun is high in the sky and are caused by ice crystals high in the atmosphere refracting and bending the Sun's light. Some are quite dim, little more than a pale grey-white circle around the Sun. The most dramatic halos are very eye-catching, taking the form of a beautiful blue-white ring around the Sun, or even rainbow-hued. You'll notice that the sky inside the halo is darker than the sky outside of it.



Sun pillar

If plate-shaped ice crystals in the upper atmosphere line up in a certain way a column of silvery-blue or sometimes golden light can appear above the Sun, but only when it is at a low altitude. This is known as a 'Sun pillar', and they often linger in the sky after the Sun has set or herald its appearance before it has risen.



Circumzenithal arc

Although most people will have seen Sun dogs, solar halos and Sun pillars, far fewer will have seen a circumzenithal arc because they appear almost overhead, and most of us are too busy looking at the panoramic view around us to tilt back our heads and look that far up in the sky very often. It's a shame, because occasionally what looks like an upside-down rainbow can be seen high above the Sun, almost overhead. This is a circumzenithal arc, a curve of rainbow-coloured light which is the brightest segment of a ring centred on the zenith, the overhead point in the sky.



TARGET #5

Lunar-planetary occultations

Very rarely it's possible to see a planet disappearing behind - or emerging from behind - the Moon. Just like ISS transits, you have to be in the right place at the right time to see one of these planetary occultations, and will also need either a pair of binoculars or a telescope to see it. If you have patience and time things just right, the view - and the experience - can be amazing.



Source: Wikipedia Commons: © Stephen Rahn

and damage them. The main drawbacks with solar filters are their expense compared to simply using projection, and the way that they only allow one person to view the Sun at a time.

There are more than just dark sunspots on the Sun's surface, but if you want to see the spectacular loops and arches of fiery gas known as prominences, or glimpse bright solar flares, you will need to dig deeper into your pockets.

If you want to see everything the Sun has to offer you will need to invest in, or borrow, a special solar telescope. These instruments are very specialised pieces of equipment featuring built-in filters which are tuned specifically to the 'Hydrogen-alpha' - or H-alpha - wavelength. Viewed in H-alpha, the face of the Sun is transformed from a blank, featureless disc to a sunspot-spattered cauldron. If there are any present at the time of viewing, prominences will look like fiery arches, loops or hoops on the Sun's

edge, and should you see a brief flash or flaring of pink or white on the disc you'll have been lucky enough to witness a rare and powerful solar flare just as it happened.

Solar telescopes offer stunning, detailed views of our nearest star, but they are very expensive, and many people find them difficult to get to grips with. An alternative would be to buy a Hydrogen-alpha filter to go over the front of your telescope, but these are quite expensive too.

If you want to see this kind of detail on the Sun but can't afford or don't have access to any of the equipment detailed above, don't worry! There are many free apps available for your smartphone or tablet and websites you can visit which show 'live' views of the Sun in optical and other wavelengths. You can use them to see how spotty the Sun is and watch prominences leap off the Sun and fall back down again.

Below: Sun dogs, also known as parhelia, are easy to spot with just the unaided eye





STARGAZER

ESSENTIAL GUIDES AND ADVICE FOR AMATEUR ASTRONOMERS

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Red light friendly

In order to preserve your night vision, you should read our observing guide under red light

What's in the sky?



Source: Wiki commons @ Joshua Tree National Park

16 JUL



Pluto reaches opposition in Sagittarius at magnitude +14.9

26 JUL

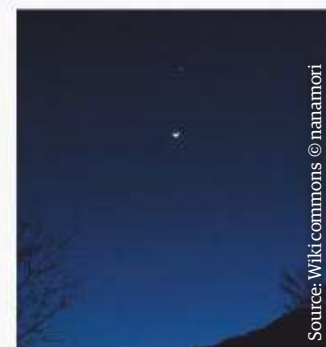


Mercury reaches half phase (dichotomy) in the evening sky, shining at magnitude -0.3

29 JUL



The Southern Delta Aquariids reach their peak of approximately 25 meteors per hour



Source: Wiki commons @ nanamori

29 JUL



The Alpha Capricornids reach their peak of approximately five meteors per hour

9 AUG



The Moon and Mars make a close approach, passing within 0°41' of each other in Pisces

12 AUG



The Perseids reach their peak of approximately 150 meteors per hour

12 AUG



Venus reaches half phase in the evening sky, shining brightly at magnitude -4.3

Jargon buster

Conjunction

A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)

This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude

An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition

When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

**17
JUL**



Conjunction between the Moon and Venus in Taurus

**20
JUL**



Saturn reaches opposition in Sagittarius, dazzling at magnitude +0.1

**22
JUL**



Mercury is at its greatest elongation west in the evening sky, shining at +0.1

**27
JUL**



Mercury reaches its highest point in the morning sky, shining at magnitude +0.1

**28
JUL**



The Piscis Austrinus reach their peak of approximately five meteors per hour



Source: Wiki commons @jbeamin

**2
AUG**



The Moon, Jupiter and Saturn make a close approach in Sagittarius

Naked eye

Binoculars

Small telescope

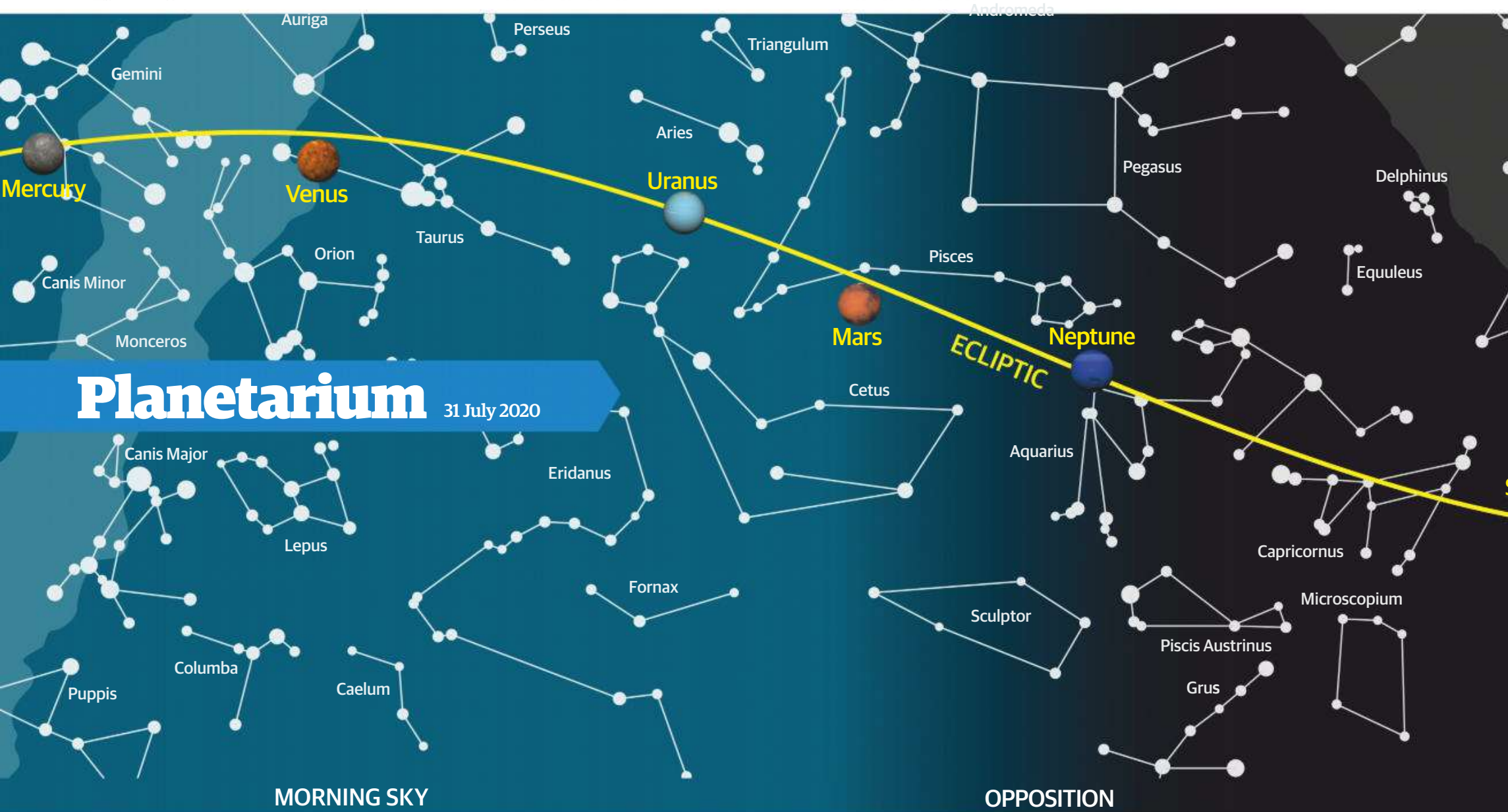
Medium telescope

Large telescope



Source: Wiki commons @ Sasha Urusov



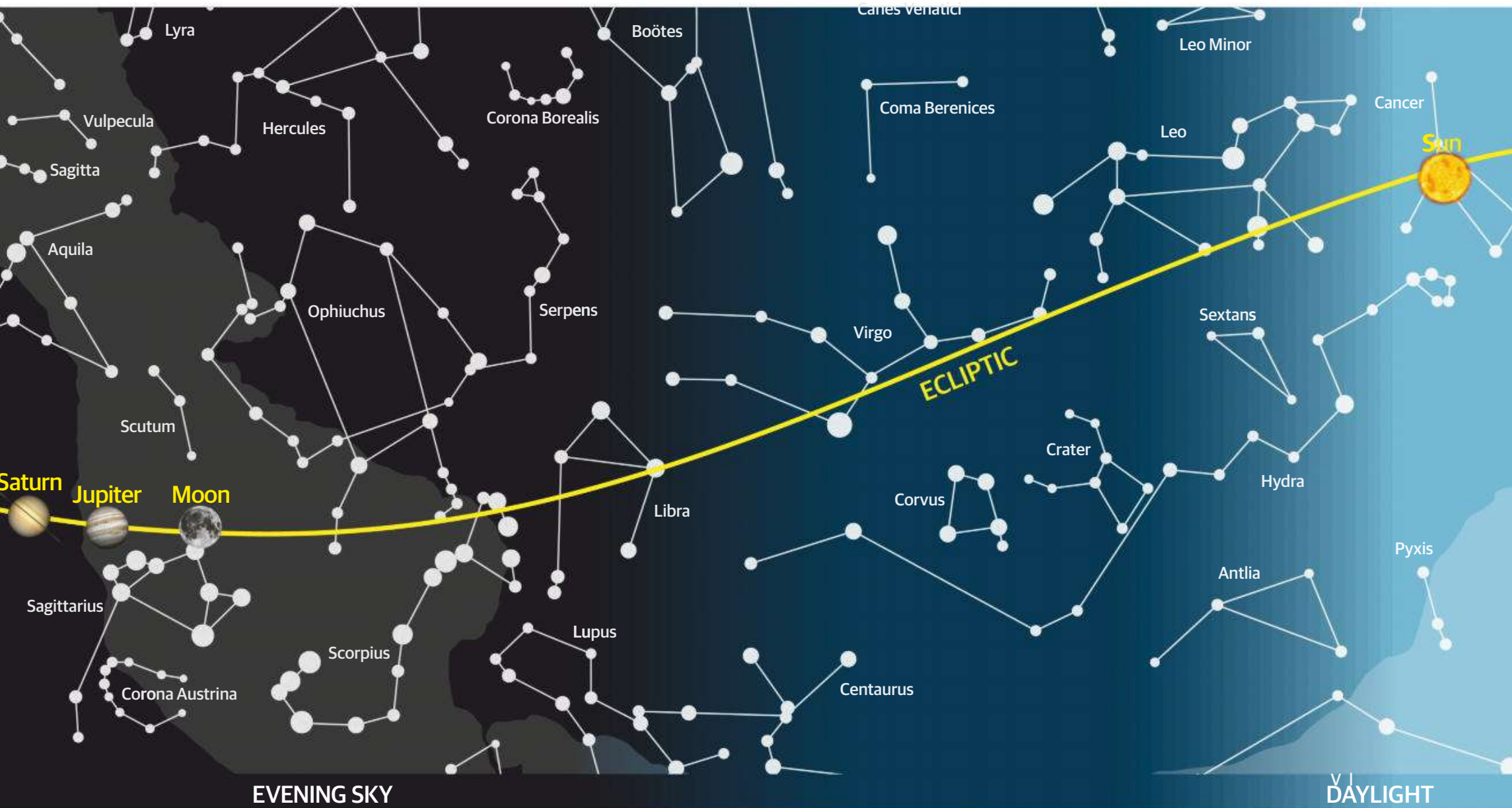


Moon calendar

* The Moon does not pass the meridian on 2 August

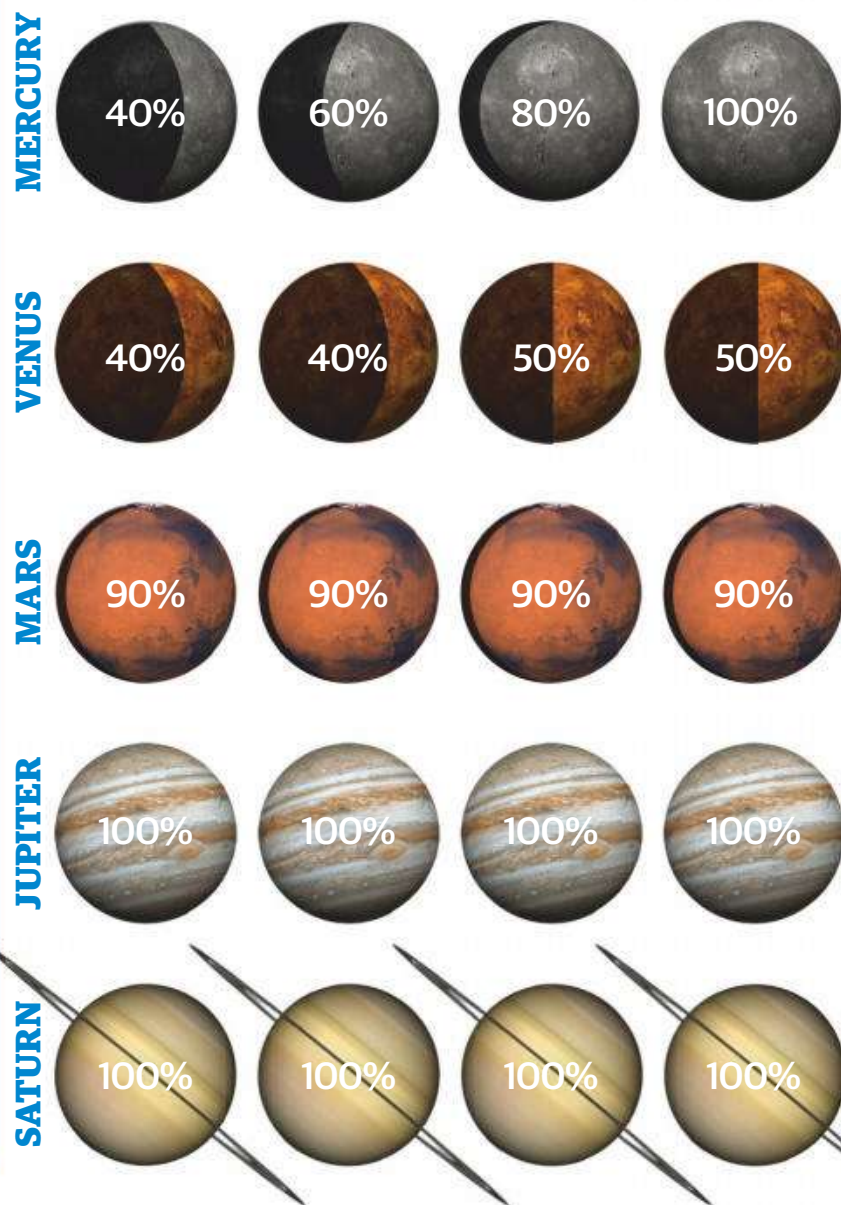
17 JUL 12.2% 02:04 18:29	18 JUL 6.1% 02:39 19:35	19 JUL 1.9% 03:24 20:33	20 JUL NM 0.1% 04:23 21:21
21 JUL 0.9% 05:33 22:00	22 JUL 4.5% 06:51 22:30	23 JUL 10.7% 08:13 22:54	24 JUL 19.2% 09:36 23:15
25 JUL 29.5% 10:59 23:35	26 JUL 40.9% 12:21 23:54	27 JUL FQ 52.8% 13:42 ---	28 JUL 64.4% 00:15 15:04
29 JUL 75.1% 00:39 16:25	30 JUL 84.4% 01:09 17:42	31 JUL 91.7% 01:47 18:51	1 AUG 96.7% 02:35 19:49
2 AUG ---%* 03:34 20:35	3 AUG FM 99.4% 04:42 21:10	4 AUG 99.8% 05:53 21:37	5 AUG 97.9% 07:05 21:58
6 AUG 94.0% 08:16 22:16	7 AUG 88.4% 09:25 22:32	8 AUG 81.3% 10:33 22:47	9 AUG 73.2% 11:40 23:03
10 AUG 64.2% 12:46 23:19	11 AUG TQ 54.6% 13:54 23:39	12 AUG 44.7% 15:03 ---	13 AUG 34.9% 16:12 00:03
14 AUG 25.3% 17:19 00:33	% Illumination Moonrise time Moonset time FM Full Moon NM New Moon FQ First quarter TQ Third quarter		

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage

22 JULY 29 JULY 5 AUGUST 12 AUGUST



Planet positions

All rise and set times are given in BST

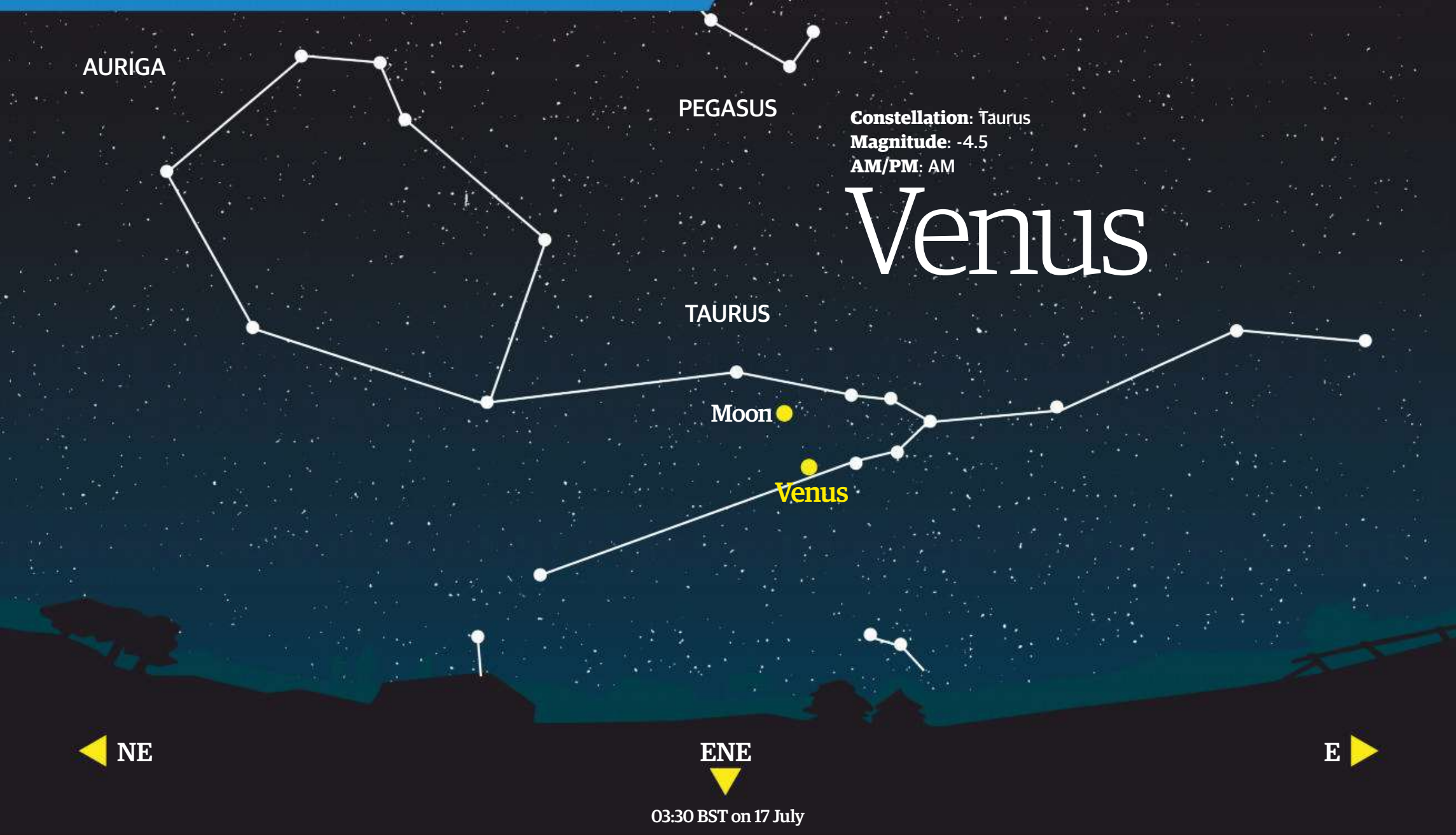
	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	17 JULY	06h 40m 12s	+20° 38' 10"	Gemini	+0.3	03:41	19:36
	24 JULY	06h 48m 33s	+20° 58' 19"	Gemini	-0.0	03:40	19:39
	31 JULY	07h 29m 12s	+21° 31' 47"	Gemini	-0.8	03:49	19:56
	7 AUG	08h 23m 25s	+20° 22' 54"	Cancer	-1.3	04:23	20:15
	12 AUG	09h 05m 21s	+18° 16' 43"	Cancer	-1.7	04:59	12:41
VENUS	17 JULY	04h 47m 14s	+17° 50' 32"	Taurus	-4.5	02:26	17:46
	24 JULY	05h 07m 18s	+18° 30' 37"	Taurus	-4.4	02:14	17:42
	31 JULY	05h 30m 32s	+19° 11' 01"	Taurus	-4.4	02:06	17:42
	7 AUG	05h 56m 20s	+19° 44' 15"	Orion	-4.3	02:01	17:44
	12 AUG	06h 16m 03s	+20° 00' 11"	Orion	-4.3	01:59	17:46
MARS	17 JULY	00h 44m 22s	+00° 56' 48"	Cetus	-0.8	23:51	12:12
	24 JULY	00h 57m 52s	+02° 11' 57"	Cetus	-0.9	23:31	12:04
	31 JULY	01h 10m 20s	+03° 19' 43"	Pisces	-1.1	23:10	11:55
	7 AUG	01h 21m 34s	+04° 19' 21"	Pisces	-1.2	22:49	11:44
	12 AUG	01h 28m 42s	+04° 56' 27"	Pisces	-1.3	22:33	11:34
JUPITER	17 JULY	19h 34m 03s	-22° 00' 58"	Sagittarius	-2.7	20:48	04:56
	24 JULY	19h 30m 16s	-22° 10' 11"	Sagittarius	-2.7	20:18	04:24
	31 JULY	19h 26m 39s	-22° 18' 38"	Sagittarius	-2.7	19:47	03:52
	7 AUG	19h 23m 20s	-22° 26' 05"	Sagittarius	-2.7	19:17	03:20
	12 AUG	19h 21m 13s	-22° 30' 44"	Sagittarius	-2.7	18:56	02:58
SATURN	17 JULY	20h 03m 16s	-20° 39' 04"	Sagittarius	+0.1	21:08	05:35
	24 JULY	20h 01m 06s	-20° 45' 57"	Sagittarius	+0.1	20:39	05:04
	31 JULY	19h 58m 58s	-20° 52' 38"	Sagittarius	+0.1	20:10	04:34
	7 AUG	19h 56m 54s	-20° 58' 59"	Sagittarius	+0.2	19:41	04:03
	12 AUG	19h 55m 30s	-21° 03' 14"	Sagittarius	+0.2	19:21	03:42



This month's planets

Venus blazes in the dawn sky from July through to August, while Mercury, Mars, Uranus and Neptune also take the morning watch

Planet of the month



Between mid-July and mid-August many summer sky-watchers will be able to see all seven of Earth's sister worlds strewn across the sky. However, one planet will dominate the pre-sunrise sky, the world that many people know as the 'morning star' or 'evening star' and is often - very misleadingly - called 'Earth's Twin'. That planet is Venus, the closest planet to Earth.

Venus is the second planet out from the Sun, and earned its stellar nicknames from the way that it sometimes blazes in the west after sunset and at other times blazes in the east before sunrise. As for that other nickname, it couldn't be less of a twin to Earth if it tried. Yes, it's roughly the same size as our planet, so there is a similarity there, but its carbon-dioxide atmosphere would be poisonous to

us, its acid rain would burn us and its furnace-hot surface temperatures would be lethal to us long before the crushing atmospheric pressure on its flat, rocky plains killed us. All of these inhospitable conditions are down to its thick, curdled atmosphere, which traps the Sun's heat and pushes the temperature on its surface to over 400 degrees Celsius (752 degrees Fahrenheit).

Ironically it's the same ugly, inhospitable atmosphere that makes Venus shine so brightly in our sky: the clouds in Venus' atmosphere reflect the Sun's light back into space like a mirror, making it shine brilliantly in our sky.

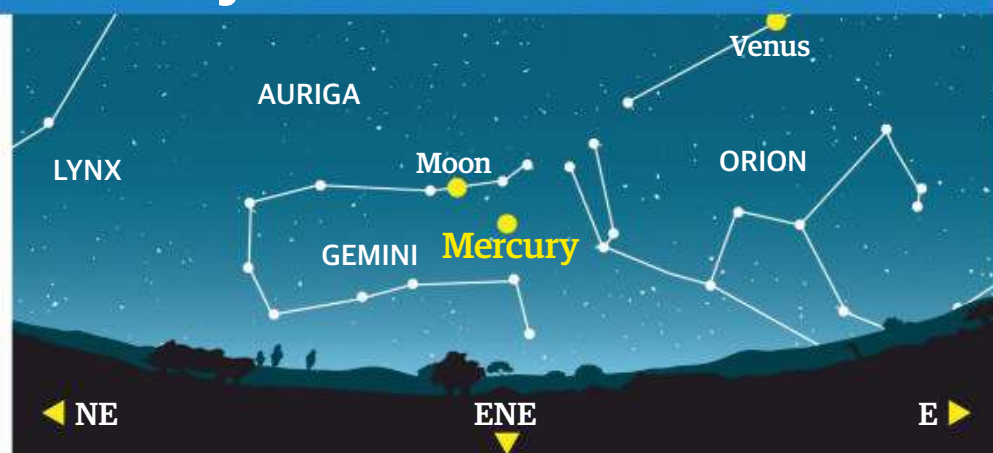
This month Venus will be visible in the east before dawn, looking like a brilliant electric blue-white spark in the sky, far brighter than any other

planet or star in the sky at that time. Venus will already be a very striking sight in mid-July, but as the mornings pass will become even more so. It will be at its best at the end of our observing period, when it will be rising at around 02:00 and visible right through until sunrise.

Venus won't just be kept company by Mercury in the sky before sunrise this month. Look out for the waning Moon approaching and then passing Venus in mid-July. On the morning of 16 July the Moon will be shining just to Venus' upper right. The following morning, on 17 July, the Moon will be shining directly above Venus, the two making a striking pair. On the next morning the Moon will have moved eastwards along its track and will be found to the lower left of Venus.



Mercury 05:00 BST on 19 July



Constellation: Gemini

Magnitude: +1.4

AM/PM: AM

Mercury, the closest world to the Sun, will be a morning star this month. At the start of our

observing period it will be shining in the northeast before sunrise at magnitude +1.4, bright enough to be visible without any help from binoculars or a telescope, though hardly striking or spectacular.

Mars 04:00 BST on 9 August



Constellation: Pisces

Magnitude: -0.8

AM/PM: AM

Mars will be a morning object at the start of our observing period, rising in the east around midnight. In

mid-July it will shine at magnitude -0.8, but by the middle of August it will have brightened considerably to an impressive magnitude of -1.2. By then it will be rising around 23:00, making it an evening object.

Jupiter 22:00 BST on 3 August



Constellation: Sagittarius

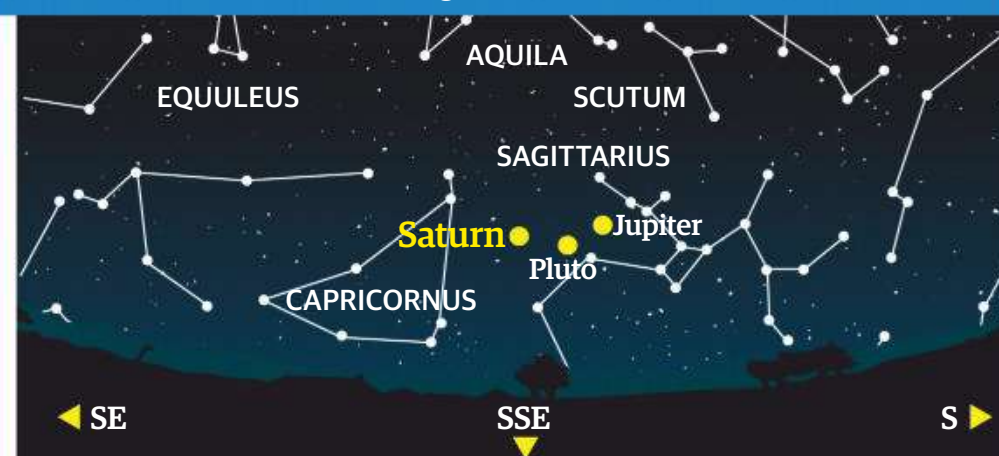
Magnitude: -2.8

AM/PM: PM

The second-brightest planet in the sky, Jupiter will rise late in the evening and then look like a bright

blue-white star to the naked eye all through the night. You'll find it to the right of fainter, golden-hued Saturn, to the upper left of the handle of the famous 'Teapot' asterism in Sagittarius.

Saturn 22:00 BST on 3 August



Constellation: Sagittarius

Magnitude: +0.1

AM/PM: PM

Saturn will be an evening object through the coming month. Looking like a yellow-white star to the

naked eye, the sixth planet from the Sun will be found to the upper left of the distinctive 'Teapot' of Sagittarius. At magnitude +0.1 it will be immediately obvious to the naked eye.

Neptune 22:30 BST on 6 August



Constellation: Aquarius

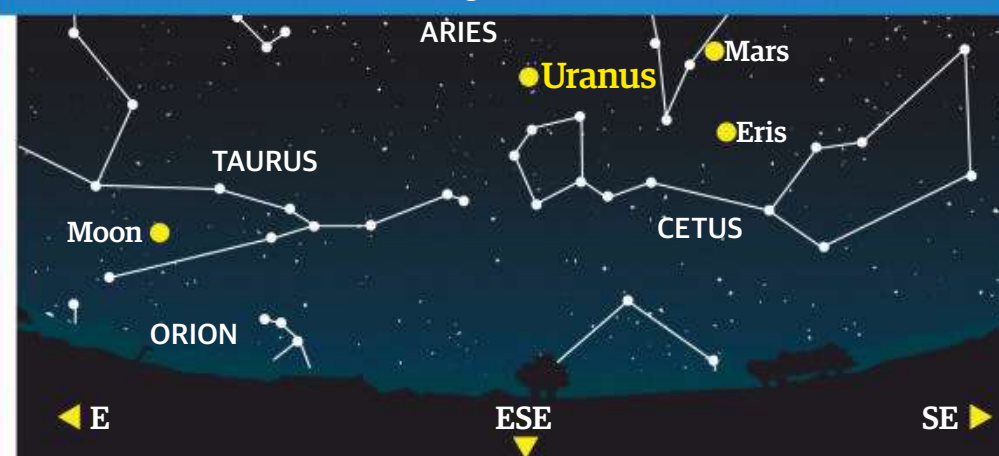
Magnitude: +7.8

AM/PM: PM

Rising around half an hour before midnight on mid-July nights, at magnitude +7.8 Neptune will be far

too faint to be seen with the naked eye - you'll need a pair of binoculars at least to see it looking like a tiny blue-green star on the eastern side of Aquarius in an area quite barren of stars.

Uranus 02:00 BST on 14 August



Constellation: Aries

Magnitude: +5.8

AM/PM: AM

This is a good month to look for and observe green-hued Uranus in the sky. In the middle of July the

seventh planet out from the Sun will be rising around 01:00 as a faint 'evening star' starting its slow arc low across the sky from east to west, and by mid-August it will be rising before 23:00.



STARGAZER

© NASA

Top tip!

Try to observe the Moon when it is still quite low in the sky - it won't be as blindingly bright as it appears when it's higher.

Eratosthenes

Sinus Iridum

Plato

Copernicus

Kepler

Tycho

Moon tour

The Perseid last quarter Moon

Our natural satellite will interfere with this month's meteor shower, but it's worth looking at in its own right

Every year amateur astronomers and sky-watchers look forward to the Perseid meteor shower, which reaches its peak mid-August. For the past few years the sky has been lovely and dark for the shower, but this year a very bright Moon will be shining close to the part of the sky the meteors come from, which will greatly reduce the number we will see. However, the Moon itself will be a fascinating sight, so this month our Moon Tour doesn't just have a single destination. Instead we're going on a sightseeing cruise around the most striking features visible on the Moon after it rises around midnight on 12 August, the date of the peak.

Once the Moon is clear of the horizon you'll see that the illuminated half is light in some places and dark in others. The light areas are the so-called lunar highlands. These are rugged, mountainous areas, dominated by jagged peaks and the deep valleys between them. They are made of very old lunar rock, and appear so bright to us here on Earth because they reflect a lot of sunlight. In contrast the dark areas are

flat, low and reflect much less sunlight. These dark areas are the famous 'seas', or mare, and they are actually vast plains of ancient, frozen lava.

Through binoculars or a small telescope you'll see a small triangle of bright spots on the illuminated part of the disc. Each of these is actually a huge crater blasted out of the Moon by the impact of a massive piece of space rock many millions of years ago. Look more closely and you'll see webs of bright lines surround these spots. These are rays of fine dusty and rocky debris that were blasted out of the Moon in the impact, sprayed away and then fell to the ground again, leaving bright streaks on the surface.

The crater at the top of the triangle is Eratosthenes, one of the youngest and brightest craters on the Moon. Some 59 kilometres (36.6 miles) wide and almost four kilometres (2.4 miles) deep, it is a lot brighter on its left. The middle crater in the triangle is Kepler, and its rays stretch for more than 300 kilometres (186 miles). To Kepler's right is Copernicus, the 'Monarch of the

Moon', a huge crater 93 kilometres (57.7 miles) from side to side and almost four kilometres (2.4 miles) deep. It was formed more than 800 million years ago by a huge asteroid striking the Moon.

Look to the bottom of the Moon and you'll see another bright crater just to the left of the terminator, the line between lunar day and night. This is Tycho, another young crater surrounded by rays formed only 100 million years or so ago.

Look to the top of the Moon now and you'll see a small, strikingly dark oval close to the terminator. This is the crater Plato. It appears so dark because its floor is flat and covered in dark, ancient lava.

Look a short distance to Plato's left you'll see what looks like a semi-circular bay cut out of the bright surface of the Moon. This is Sinus Iridum, the Bay of Rainbows, and it's the surviving half of a crater that was flooded by lava many millions of years ago. It's considered to be one of the most beautiful landscape features on the Moon.

Naked eye & binocular targets

Look in and around the Northern Cross and you'll find lots of summertime celestial wonders

Messier 39

This triangle-shaped spray of almost 30 stars is a very pretty sight in binoculars and can even be seen with the naked eye under a dark sky. An open cluster, M39 is often overlooked because it is not bright or as obvious as other star clusters in the region.

Cygnus X

On dark, Moon-free summer nights unspoiled by light pollution you'll see a long, smoky smudge running down the right-hand side of the Northern Cross. This is the Cygnus star cloud. Binoculars will show it is made of countless millions of faraway stars, glittering like diamond dust.

Deneb (Alpha Cygni)

The 19th-brightest star in the sky, Deneb shines at magnitude +1.3. This blue-white star is the brightest star in Cygnus and is a supergiant star many thousands of times more luminous than our own Sun. It was the Pole Star 18,000 years ago and it lies over 1,400 light years away from Earth.

North America Nebula (NGC 7000)

This huge nebula is 100 light years across and 2,600 light years away. You'll need a clear Moon-free night with no light pollution spoiling your view to see this famous nebula with your naked eye, looking like a pale smudge close to Deneb. Binoculars show it as a slightly misty area, larger than the Moon.

Albireo (Beta Cygni)

Albireo is one of the most famous double stars in the sky, with gold and indigo components, although recent studies suggest it is just a visual binary, not a pair of stars orbiting each other. It can be found at the head - or tip of the 'beak', depending on how detailed a star map you are using - of Cygnus, the Swan.

Lyra

Cygnus

Vulpecula

Sagitta

Deep sky challenge

Treasures of the Great Square of Pegasus

Forget the stunning Andromeda Galaxy and enjoy some of the many other fascinating objects lurking nearby

Easily visible to the naked eye late on Moon-free summer nights as a smudge of light larger than the Moon, the Andromeda Galaxy (M31) is one of the most beloved and most frequently observed and photographed deep-sky objects. Even a small telescope transforms that smudge into a beautiful misty oval, and larger instruments can show not just tantalising hints of its spiral structure, but its pair of fainter satellite galaxies and its bright, curdled core.

It's easy to spend a whole night just looking at Andromeda, but close to it you can find many other deep-sky objects worthy of your telescope's attention. They are much more challenging to see because they are much smaller and fainter, but because they are so different to big, brash M31, they are definitely worth tracking down.

A couple of this month's challenges are really only worth looking for with large-aperture, light-gulping

telescopes under a sky that's unaffected by light pollution - the closer to new Moon the better, too. Others will be visible through smaller instruments, but all are hard to see. In fact, one can't be seen at all, not even through the largest telescopes in the world. So why have we included it on our list this month? Because sometimes in astronomy the satisfaction comes from knowing what you're looking at, rather than how amazing the view actually is.

Mirach's Ghost (NGC 404)

"BECAUSE THEY ARE SO DIFFERENT TO BIG, BRASH M31, THEY ARE DEFINITELY WORTH TRACKING DOWN"

The Little Sombrero (NGC 7814)

© NASA/JPL-Caltech

© ESA/Hubble & NASA

1 NGC 7479

This barred-spiral galaxy is undergoing violent starburst activity. Shining at +11.6, it is visible in almost any telescope, but you'll need medium or large apertures under a dark sky to find it.

2 The 'Taffy' galaxies (UGC 12914)

Expect to see nothing more than a dim, elongated smudge through a large-aperture telescope, even at high power. This barely-there galaxy is more than 163 million light years away.

3 Pegasus Dwarf Galaxy (UGC 12613)

If you have a large telescope and a very dark sky you might be able to pick this +12.6 galaxy out. It is a quite large, extended object visually, but its low surface brightness makes it very challenging.

4 The Little Sombrero (NGC 7814)

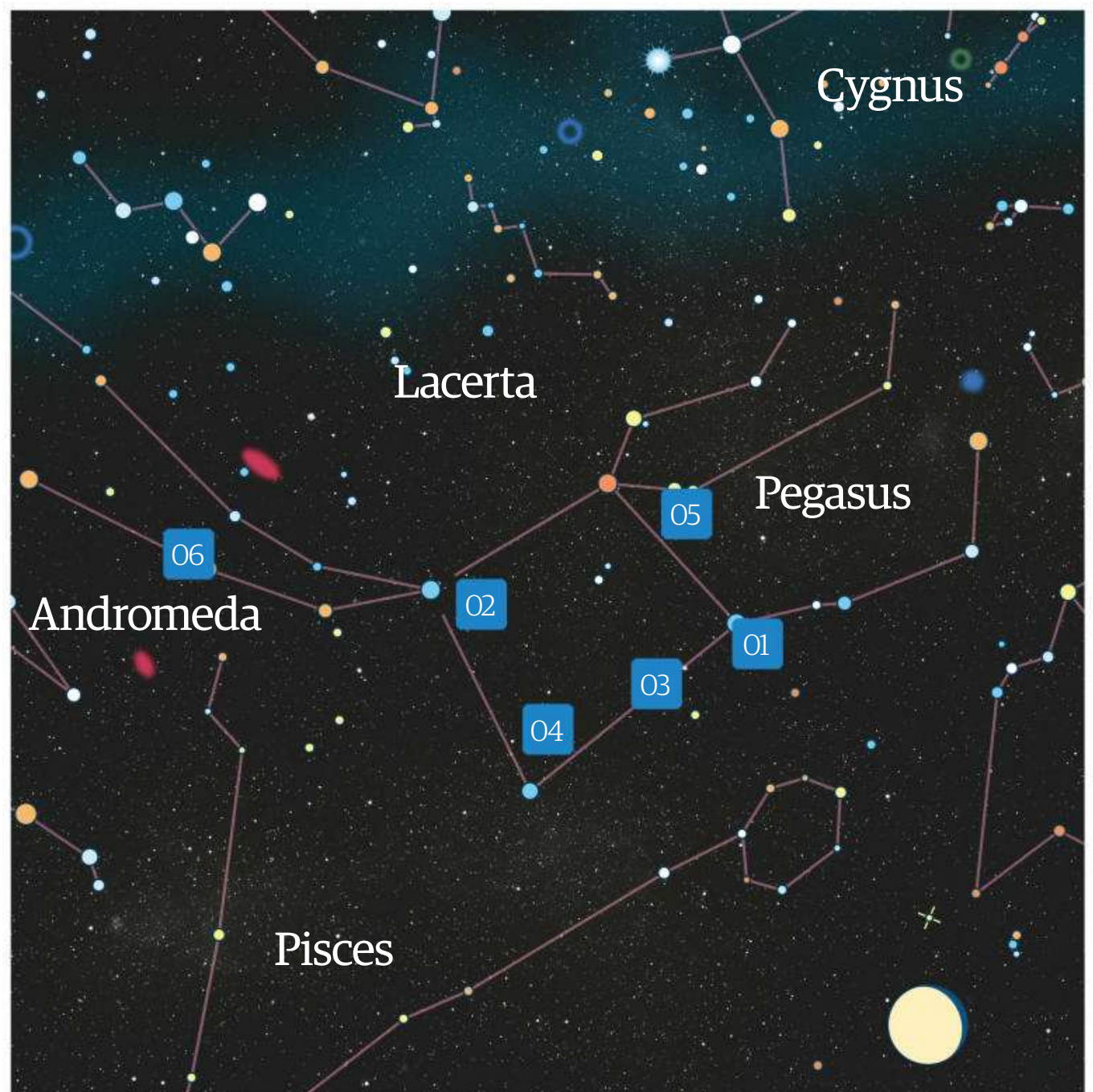
Larger apertures will show this galaxy as an elongated misty patch with a dark central band. Seen edge-on from our point of view, it owes its nickname to its resemblance to the larger M104.

5 51 Pegasi (Helvetios)

Finding this star is no challenge, but it is worth taking a look at through any telescope because it was the first Sun-like star found to have a planet - now named Dimidium - orbiting it.

6 Mirach's Ghost (NGC 404)

Almost lost in the glare of bright star Mirach, this irregular galaxy can be glimpsed in small telescopes as a tiny smudge. You'll need a medium- or large-aperture telescope to see it properly.





The Northern Hemisphere

Bright nebulae grace the August skies, offering an impressive night-sky selection

Heading into the warm month of August, there's an impressive array of targets suitable for observers armed with binoculars, telescopes or those who are just content with gazing upon the night sky with the unaided eye.

Galaxies and star clusters are abundant. However, it's the nebulae within constellations such as Cygnus and Lyra that are the objects to look to this month. The Ring Nebula (M57), the Pelican Nebula (IC 5070 and IC 5067), young and dense planetary nebula NGC 7027, reflection nebula NGC 6914 and the 'blinking planetary' NGC 6826 are particularly impressive, providing plenty of observing and imaging opportunities for astronomers and astrophotographers alike.

Using the sky chart

This chart is for use at 22:00 (BST) mid-month and is set for 52° latitude.

- 01 Hold the chart above your head with the bottom of the page in front of you.
- 02 Face south and notice that north on the chart is behind you.
- 03 The constellations on the chart should now match what you see in the sky.



Magnitudes

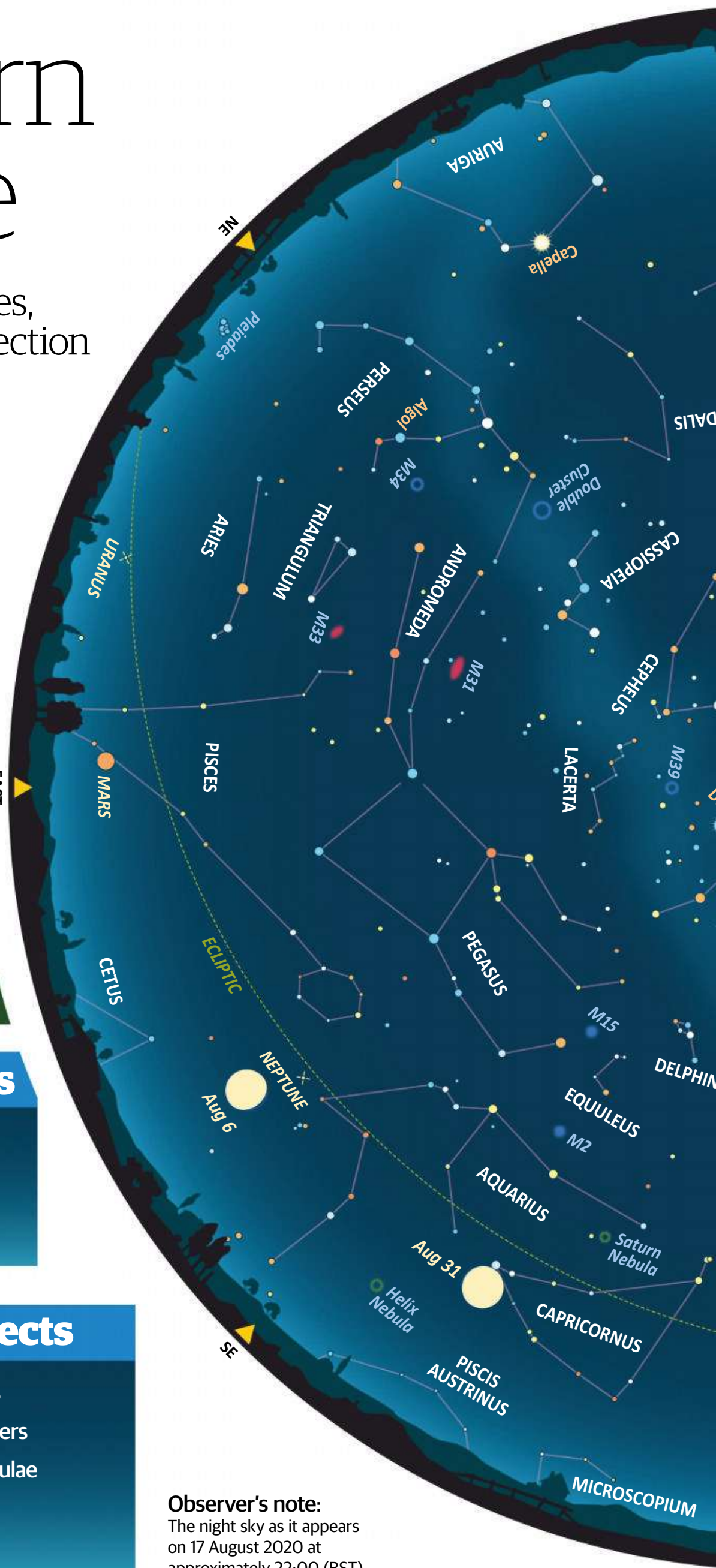
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

- | | |
|-------|-----|
| • O-B | • G |
| • A | • K |
| • F | • M |

Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



Observer's note:

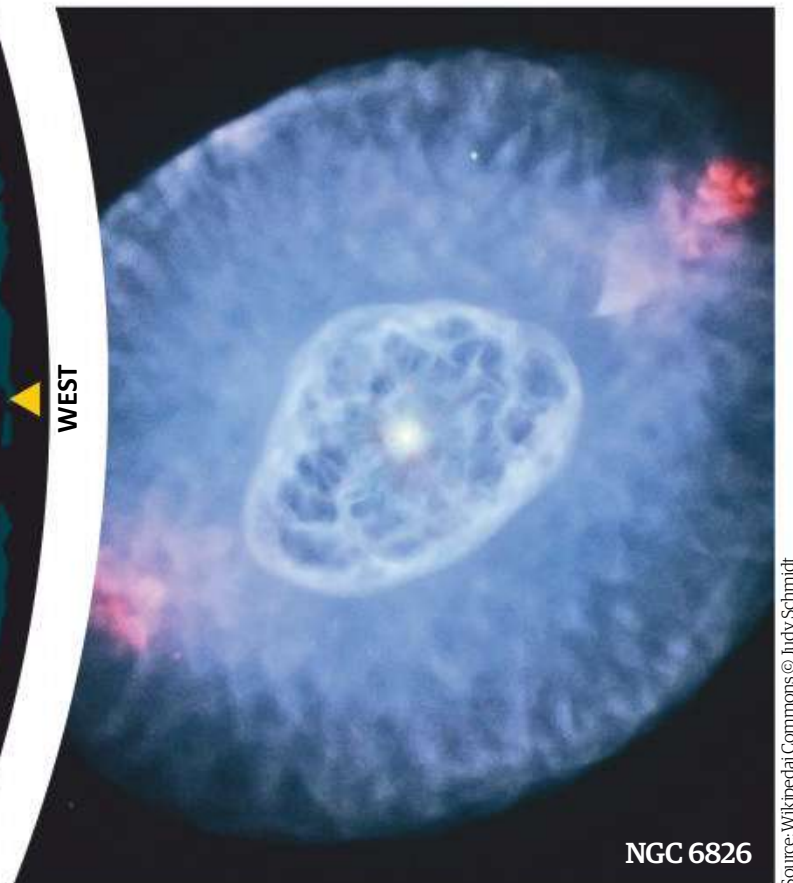
The night sky as it appears on 17 August 2020 at approximately 22:00 (BST)



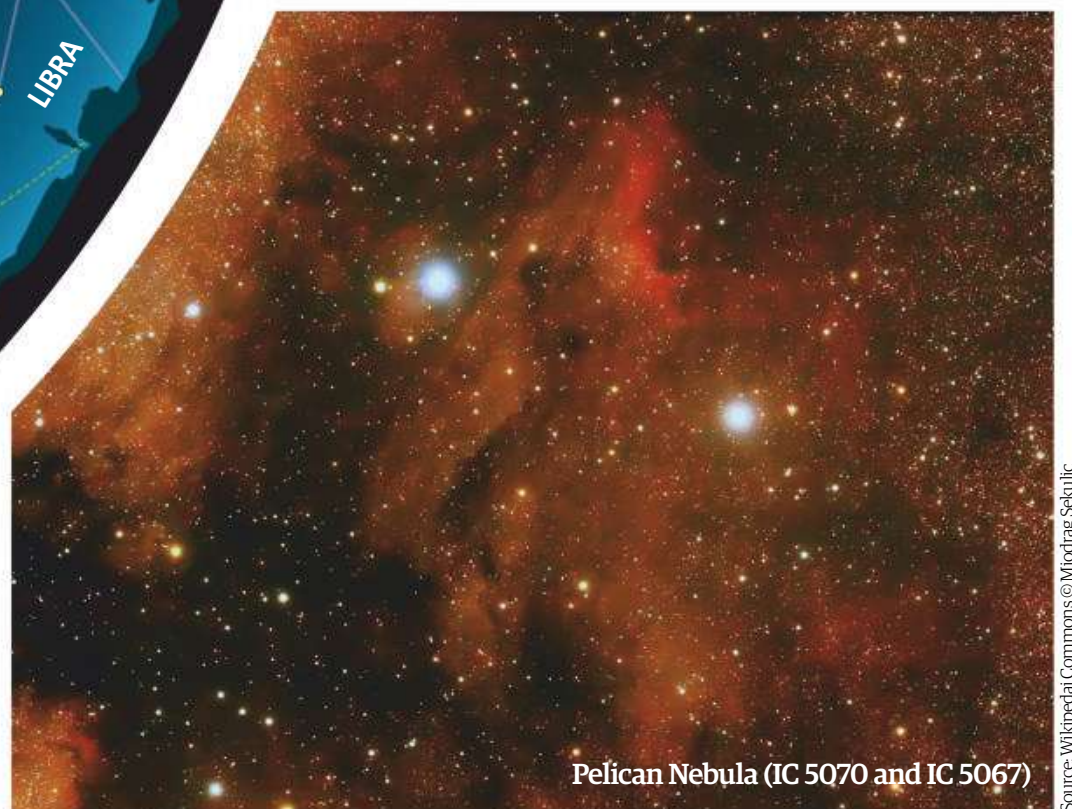
The Northern Hemisphere



Source: Wikipedia Commons © Adam Block/Mount Lemmon Sky Center/University of Arizona



Source: Wikipedia Commons © Judy Schmidt



Source: Wikipedia Commons © Miodrag Sekulic



Omegon MightyMak 90

Highly portable, simple to use and ideal for beginners on a budget, this small telescope is an excellent introduction into astronomy

Telescope advice

Cost: £179 (approx. €195)

From: astroshop.eu

Type: Maksutov-Cassegrain

Aperture: 3.54"

Focal length: 39.37"

Best for...



Beginners



Small budgets



Planetary viewing



Lunar viewing



Terrestrial viewing



Basic astrophotography

If you're looking for a telescope that's easy to carry and set up ready for your very first venture into observing, or perhaps you have children that have been hassling you for a 'scope, but you don't want to spend a fortune on a hobby that could end up being a fad, then the Omegon MightyMak 90 is a worthwhile option to consider. Omegon's affordable product provides two types of mount - a tabletop tripod and a Dobsonian - ideal for quick wildlife watching and night-sky viewing - as well as a Kellner 25mm eyepiece and a handy transport bag.

Unusually, however, there doesn't seem to be a finderscope or red dot finder to assist with finding objects, something that may hinder a novice astronomer's observing sessions to a large degree. For the purpose of this review we attached an in-house red dot finder to the telescope in order to test it sufficiently.

Overall the MightyMak 90 is very well built; the tube in particular is of superb quality. The build of the Dobsonian mount is good, but the tabletop tripod doesn't seem to support the tube as well without severely tightening the tripod pan handle. The MightyMak 90 is sufficiently packaged in bubble wrap to ensure safe transportation. The dust cap, which is fixed to the telescope's objective lens, is a nice touch, ensuring that you don't lose this important accessory, although it could become a hindrance while observing, particularly on a windy evening.

We selected the sturdier Dobsonian mount for our observations. Setting up was a breeze, and within moments we got stuck into targeting a selection of objects. With its small aperture the MightyMak 90 is only really suitable for observing Solar System targets and the surface of the Moon - highly recommended targets for those just starting to observe the night sky. Slewing from one region of the sky to the other, we enjoyed the smooth operation, while still giving just the right amount of resistance for stability when observing chosen targets. With Saturn and Mars recently

reaching opposition, we quickly located the pair as yellowish and red stars not too far apart from each other in the constellations of Ophiuchus and Libra respectively, while Jupiter proudly shone as a bright star in the constellation of Leo.

We made Jupiter our first target, which appeared as a bright disc. By using averted vision we could make out two of its prominent bands - an impressive feat given the small aperture of this telescope. The MightyMak 90 allows for basic astrophotography, which we took advantage of, and which allowed us to reveal much more subtle detail across the gas giant's equator. Three of the planet's four Galilean moons were visible during our observations, appearing as lined-up points of light either side of Jupiter's limbs.

The MightyMak 90's clarity is impressive, with no chromatic aberration - or colour fringing - visible on the edges of such a bright object. Mars appeared as a small, salmon-pink disc over the southern horizon, while the ringed giant Saturn stole the show at magnitude +0.8. While the view of the planet was small in the field of view, the planet's majestic rings blew us away. Although conditions weren't favourable enough to pick out the Cassini Division without the aid of photography equipment, the MightyMak 90 surpassed expectations. The manual to the Maksutov-Cassegrain states that the 'scope isn't very useful in observing deep-sky objects. While on the whole this is true of this desktop 'scope, it is capable of picking out rich star clusters, as well as brighter nebulae.

The MightyMak 90 is perfect for those wanting to get into astronomy without breaking the bank. Being suitable for terrestrial views, the 'scope also doubles up for watching wildlife, adding more value for money. While the telescope came without a finderscope and could have been supplied with a few more accessories, the MightyMak is versatile and suits a wide range of eyepieces and filters. There are cheaper 'scopes on the market of a more substantial size, but this 'pint-sized' model has an advantage thanks to its portability.

Below: The Maksutov-Cassegrain's tube didn't feel sufficiently supported by the 'wildlife watching' tripod





"THE MIGHTYMAK 90 IS
VERSATILE AND SUITS A
WIDE RANGE OF EYEPIECES
AND FILTERS"



Above: The telescope tube employs a Maksutov-Cassegrain design for good views of Solar System targets

Sir Joseph Norman Lockyer

One of the discoverers of helium, Lockyer was a huge advocate of studying the Sun

Joseph Lockyer was an amateur astronomer with a genuine passion for the subject. During the 19th century he would go on to be the co-discoverer of the second most abundant element in our universe and the founder of one of science's most influential journals: *Nature*.

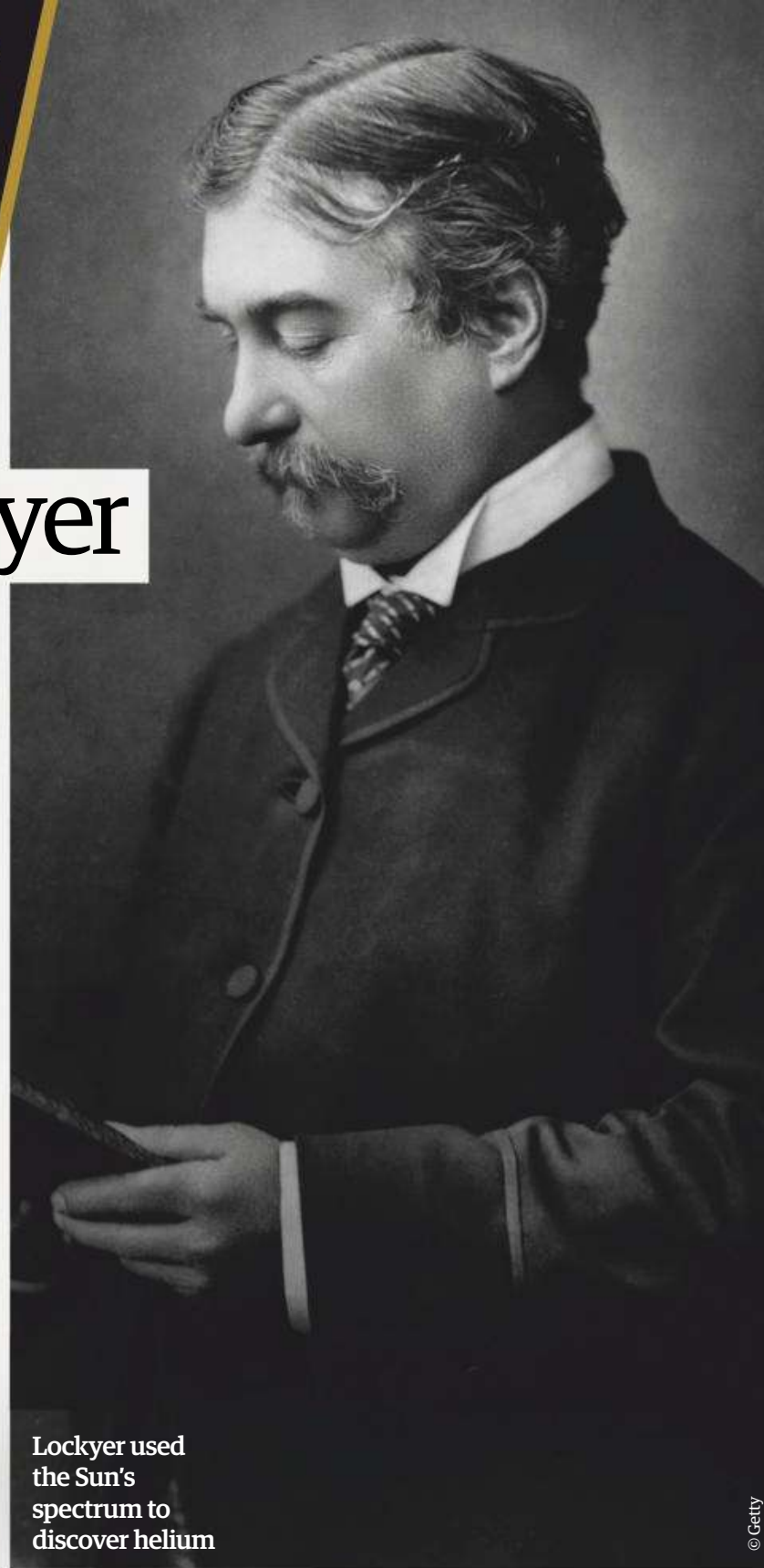
Born on 17 May 1836 in Rugby, Warwickshire, England, Lockyer delved into the world of physics concerning celestial bodies in 1859 after the discovery of spectroscopic analysis. This new scientific technique involved splitting up the light from a source into a spectrum, visually similar to a rainbow. This groundbreaking technique opened the door to the study of the elementary make-up of celestial objects, and this was the basis of what made Lockyer a renowned astronomical pioneer.

A tribute to Lockyer in the *Publications of the Astronomical Society of the Pacific* in 1920 states that his contributions to the realm of astronomical science began in 1866 with studies revolving around solar sunspots. His notes stated that the spectra lines - the lines in a spectrum attributed to the presence of a particular element - were different in sunspots when compared to the photosphere.

In 1868 Lockyer observed solar prominences using his spectrograph and noticed an unusual yet prominent yellow line in the Sun's spectrum. Previously this had been attributed to sodium. The discrepancy, however, was that it did not occupy any of the same positions as the more well-known sodium lines. This yellow line was given the name 'helium' by Lockyer, named after the Greek word 'Helios', meaning Sun.

But Lockyer wasn't the only one to make this discovery. Just after Lockyer's methodical written description arrived at the Paris Academy of Science, French astronomer Pierre Janssen submitted a similar manuscript of the same discovery. Janssen's observations were made during the total solar eclipse in August 1868. Because each of these gentlemen had handed in their fascinating work at the same time, they were awarded joint credit.

This fuelled Lockyer's obsession with spectroscopic analysis of the Sun and other



Lockyer used the Sun's spectrum to discover helium

stellar targets. He directed eight expeditions across the world to observe total solar eclipses, including journeys to Sicily in 1870, India in 1871 and India again in 1898. He also began studying the compositions of other stars in the cosmos using his trusted spectroscopic analysis.

In 1869 Lockyer founded the general science journal *Nature* - which is still published to this day - as a place to share pioneering research of every discipline with like-minded enthusiasts. It is now internationally recognised as a leading scripture for scientific and technological news. For half a century Lockyer was the editor of the journal, and this only ended because his life came to its end.

Lockyer passed away at his home in Salcombe Regis, Devon, on 16 August 1920. His work created profound ripples throughout science and astronomy and resulted in him receiving a knighthood. This all originated from his passion and his ability to build up his knowledge using the new technologies of the time - in this case the spectroscope. Despite his accomplishments, Lockyer was merely an amateur astronomer intrigued about the inner workings of the universe who strived to know more.

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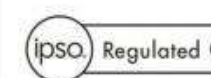


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